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ABSTRACT

This document represents the second revision of a similar guide (no longer in print) originally published in 1974. It was developed to help teachers in Arizona encourage students to: (1) become aware of human dependence on natural resources; (2) gain a fundamental understanding about our natural resources; (3) intelligently react to problems of waste and damage to natural resources, and (4) search for solutions. The guide contains chapters on the sun, water, geology, soil, plants, animals, climate, and humans and the environment. These list and discuss a set of concepts. The background information and explanatory material within these chapters was developed to help teachers understand each concept. A major portion of the guide provides 34 teaching activities which address these concepts and are keyed to different grade levels and subject areas. Another section of the guide includes a set of fact sheets containing questions and answers about various natural resources. Also included is a glossary of terms and a set of references. (TW)

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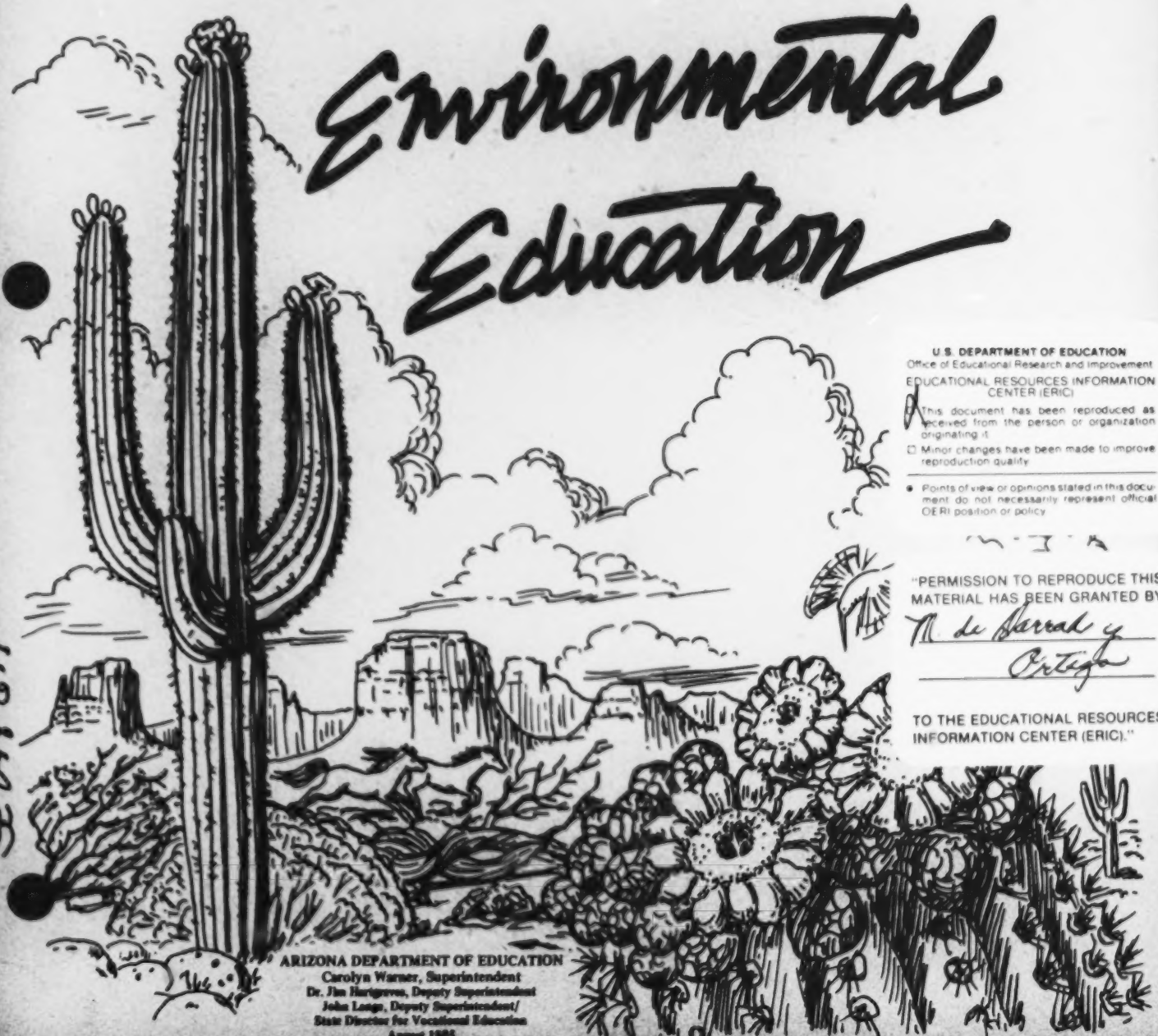

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ACTIVITY	SUBJECTS	GRADES	UNDERSTANDINGS
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Wet Dirt	A,H,L,S	K-12	Water 4B, 4C, 5A Soil 1C, 3A, 4A, 5A
Terrarium Transpiration	A,L,S	K-12	Water 1B, 2A, 2B, 2C, 4A
Where's the Water	A,G,L,R,Sp	K-3	Water 1
Water Magic	Ar,H,L,S	K-4	Water 1B, 5A
Arizona's Geologic Treasury	R,S,SS,	5-12	T.Geol. 1C, 2B, 2C, 3, 4
Hidden Waters Under the Desert	S	6-12	T.Geol. 1C, 4A, 5D
Don't Knock the Rock	S	3-11	T.Geol. 1A
Raisin Bread "Mining"	S,SS	6-12	T.Geol. 2C, 4A
Digging for Facts	Ar,L,S	K-12	Soil 2A
Rock Grinding	Ar,S	K-8	Soil 1A, 1B, 1C, 2B
Wiggly Worms	L,S	K-12	Soil 2C, 4B, 4C
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Plant Brakes	Ar,L,S	K-12	Plants 3 Soil 2C, 3B, 4C Water 4A

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Plant Energy	A,L,S	K-12	Plants 4B
Plant Cover	L,S	3-12	Plants 1C
Plants-Who Needs Them	A,L,S	6-9	Plants 1D, 4A
Rainbow Celery	L,S	K-12	Plants 1C
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And the Wolf Wore Shoes	L,R,S	2-5	Animals 5B
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Rainfall and the Forest	AH,G,L,S	5-12	Water 2A, 3A, 3C, 5
Deadly Links	PE,S,SS	4-9	Animals 1D, 2B, 2D, 5D, 5E
I'm Hungry	A,Hi,L,S,SS	K-12	Humans 1A, 2C, 2D, 2E, 3A, 3B 3D, 4A
Moon Trips	Ar,G,L,S	K-12	Humans 1A, 1C, 2B, 2D, 3B, 3C 4A, 4C
Life Styles	A,Ar,Hi,L,SS	K-12	Humans 1B, 2A, 2B, 2D, 2E, 3A 3B, 4B, 4C, 5A, 5B, 5C

SUBJECT REFERENCES

A - Art AH - Arizona History Ar - Arithmetic C - Civics G - Geography

H - Health Hi - History L - Language Arts PE - Physical Education R - Reading

S - Science Sp - Spelling SS - Social Studies

HOW TO USE THIS GUIDE

This is the second revision of this guide which was originally released in the spring of 1974. Its purpose was to help the teacher encourage the student to (1) become aware of man's dependence on natural resources, (2) gain fundamental understanding about our natural resources, (3) intelligently react to problems of waste and damage to natural resources, and then (4) search for solutions. In this revision we have left out some of the problems of waste and damage and stressed the intelligent use of natural resources in a world where demand for products is escalating at a tremendous rate.

There are still chapters on each of the seven fundamental resources which list and discuss a set of concepts and understandings about each resource. The background information and explanatory material within these chapters was written to help you as a teacher understand what we meant by each concept and understanding. The activities in the activity section are designed to help you teach the concept and/or understanding to your students.

As a teacher, you will probably find many different ways to use this guide. We could see it used as the basic curriculum for a science course on the environment. Hopefully it will be useful as a supplement to your basic curriculum in several areas, especially science, when you want to relate a discussion of one of the basic resources to Arizona. We have attempted to use Arizona examples to illustrate each understanding so that it would be more meaningful.

Each activity has a reference block which lists the subject areas and skills taught through that activity. We hope that this information will be helpful as you select appropriate activities for your students. In addition, we hope the activities will reinforce basic Math or English skills and at the same time pass on some feelings and knowledge about the environment.

However you use this guide, we hope that you will pass ideas on to others and add useful material to your copy.

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OUR SUN

Notice to Teachers:

The other chapters in this book deal with concepts that are broad enough to be applied at most grade levels. However, the concepts developed in this chapter are geared for upper grade level students.

Teachers of lower grade level students will probably want to develop the following two concepts with their students.

- The sun is our original source of energy.
- The sun is a star.

BACKGROUND

Although our sun is a very ordinary star, it is very special to the earth and its inhabitants. It is indispensible to our well-being. It is the source of virtually the entire energy streams which course through and mold the various energy systems of the earth. It has helped to modify the atmosphere over geological times to make it amenable to life as we understand it today. It provides us with light and heat, it powers our weather systems and climates, it indirectly shapes our landscapes, and it provides humankind with the energy to produce food, shelter, and clothing.

Early humans realized the sun was a source of heat and light. Without adequate explanations, they conceived the sun to be a beneficial god/goddess, and worshipped it. Later, as agricultural practices began, early humans realized, consciously or otherwise, the effects of the sun on our daily life. No longer did the sun simply start and end the day; for now we realized the sun also controlled our food supply.

Humans began to practice sun worship. In fact, all the early civilizations practiced sun worship. In the Americas, the Aztecs practiced sun worship, as did even earlier peoples. In Europe, the Druids practiced sun worship, as did the Egyptians and ancient Chinese. Today, we no longer worship the sun as a deity; we do, however, recognize the power and influence of the sun in our daily lives. Farmers still plant and harvest by the sun. Increasingly, sun power is being harnessed by humans as an energy source. Water is heated for domestic and industrial uses; sunshine is converted directly into electricity in remote areas to provide lights and refrigeration. Our satellites in earth orbit are powered by solar energy. Even our physical well-being can be directly related to the sun.

CONCEPT NO. 1: The sun is part of the universe.

The universe is the collection of space and time as we know and understand it. It is huge beyond our wildest imaginations, and becoming larger. The earth is a satellite of the sun, much as the moon is a satellite of the earth. Just as the earth "belongs" to the sun, so too, does the sun belong to a larger assemblage of stars, our local galaxy. But our local galaxy is but one of millions of others, each of which is composed of an assemblage of individual stars, dust and gases.

Astronomers study starlight as well as other forms of radiation from these other stars and galaxies to learn more about them. We want to learn what they are made of and how the individual stars react with one another: how the stars generate their energies; their births, lives, and deaths.

UNDERSTANDING A: The universe is populated with millions of galaxies.

The universe is made up of millions of galaxies. Each galaxy is a collection of billions of individual stars. Most galaxies are so far away they can only be seen with powerful telescopes.

Our sun also belongs to a galaxy, the Local Galaxy. Our Local Galaxy is also a collection of billions of individual stars. We can discern our local galaxy at night as a band of light across the sky, the Milky Way. Our sun is located near the edge of our galaxy. The Andromeda galaxy is the only one which can be seen with the naked eye. It appears as a hazy cloud. But when seen through a telescope, one can discern billions of individual stars. The individual stars in each galaxy are moving about a common center.

Recent studies indicate that, unlike the planets in our solar system, the stars farther from the center of a galaxy move faster than those nearer the center. The universe at the present time is also expanding; that is, the galaxies appear to be moving away from each other.

UNDERSTANDING B: Astronomical distances are enormous and are the largest measurements known to humankind.

The fastest phenomenon known to humans is light, which travels at about 186,000 miles per second. At this speed, a flash of light can travel a distance equal to 7½ times the circumference of the earth in one second. This has been confirmed by radio waves, a cousin of visible light, which travel at the same speed. Since the sun is 93 million miles from earth, light requires 8 1/3 minutes to make the journey. As the Pioneer satellite was leaving our solar system, radio signals sent back to earth required about ten hours to reach the earth.

PLANET	DISTANCE FROM SUN (millions of miles)	TIME FOR LIGHT TO REACH PLANET (hr., min.)
Mercury	36	0 3 1/4
Venus	67	0 6
Earth	93	0 8 1/3
Mars	142	0 12 1/4
Jupiter	483	0 43 1/3
Saturn	886	1 19 2/5
Uranus	1783	2 40
Neptune	2794	4 10
Pluto	3670	5 29

The star closest to our sun is Proxima Centuri. Light from this star reaches the solar system, and the earth, after a journey of four years. Light from the Andromeda Nebula, our closest galactic neighbor, requires almost two million years to reach us.

UNDERSTANDING C: We are seeing galaxies and events that were.

Astronomers glean information about other worlds and galaxies from the radiation received from them. There is no faster way known to transmit information. Light received from the sun requires 8 1/3 minutes to reach the earth. When we see something on the sun, the information is already 8 1/3 minutes old. Light from the closest star requires four years to reach the earth: we see events that occurred four years ago. The farther out into space we look, the older are the events we see. As we look out into space, we are looking backwards into time: we are seeing things as they were, not as they are. Some of the more distant galaxies we can see today may no longer exist!

CONCEPT NO. 2: The nature of radiation.

Stars radiate energy. We study the radiation to learn about stars and our own sun.

UNDERSTANDING A: Radiation has definable characteristics.

Radiation is energy transmitted by the combination of electric and magnetic waves interacting together. One characteristic is the wavelength: it is the distance between adjacent wave crests. It is perhaps best visualized by water waves. Imagine a stone dropped into a quiet pool of water. As the stone enters the water, it creates a series of waves which spread to the edges of the pool. As the waves move away from where the stone entered the water, the distance between neighboring waves remains the same. This distance, from the top of one wave (the crest) to the top of the next wave, is called the wavelength. It is symbolized by the Greek letter lambda, "λ". Electromagnetic wavelengths vary in size from the extremely small to the extremely long.

A spectrum is the collection of all wavelengths of a kind. The electromagnetic spectrum is the collection of all wavelengths of electromagnetic energy. For convenience in use, the electromagnetic spectrum is divided into many smaller parts. The shortest wavelengths are seen to be the gamma rays. As the wavelengths of the radiation increase, they pass through the X-rays, the ultra-violet, the infra-red, the microwave to the radio waves. The only difference between these classes of waves is the wavelengths. Note that near the center of the spectrum lies the visual band, the narrow range of the spectrum to which our eyes are sensitive. All wavelengths travel at the same speed, 186,000 miles a second.

Another, related way of differentiating wave is by the frequency of the waves. The frequency is designated by the Greek letter mu, "μ". Frequency is the number of individual waves passing a point in a given length of time, say, the second. Returning for a moment to the stone dropped into the pool of water, the waves spread out until they reach the shore. The number of waves that reach the shore in a period of time is the frequency. It is the speed of the waves divided by the wavelength. Either system of measurement can be used. Ham radio operators, for example, normally use wavelengths to describe where they may be found, the 30 meter band, while radio stations use frequencies: KTAR-620 on your dial!.

Amplitude is a second characteristic of electromagnetic waves, and indicates the energy carried by a certain frequency. Just as in water waves, the larger the wave, or the larger the amplitude, the more energy the wave carries. We are all familiar with ultra-violet radiation in too large a dosage (too much sunshine) causing severe sunburn. Shorter wavelengths (the X-ray and gamma rays) will also produce adverse effects in the body,

unless precautions are observed to limit the dose. Fortunately, our atmosphere filters out the harmful radiation wavelengths.

UNDERSTANDING B: Radiation is governed by certain physical laws.

Radiation is subject to certain natural laws. The most basic law, from which the others may be derived, was discovered by Max Planck. This law states two things: first, if a body has temperature, it will radiate energy; second, the energy radiated will be distributed over the entire spectrum, but not uniformly. Very short waves and the very long waves carry little energy. The strongest wavelengths are about a half a micron in length, in the middle of the visual band.

The second law of radiation is Wein's Law. This law states that the warmer the radiating body, the shorter will be the wavelength that carries the maximum energy. A simple experiment can be used to demonstrate this relationship. Turn on a hot plate. When the plate is first turned on, the filament is dark. As the filament grows warmer, it begins to glow with a very deep red color, and some heat is noted. As the filament continues to become warmer, the color changes to a cherry-red, to orange and to yellow. As the filament becomes warmer, the color of the filament moves to a shorter wavelength. At the same time, the heat output of the filament increases.

The third radiation law is that of Stefan Boltzmann, relating the total radiant energy output of a body to its temperature. The law states that, if the temperature of a body is doubled, the energy output is increased 16 times.

Laws of Radiation

Planck's Law - If a body has temperature, it will radiate energy. This energy will be distributed over the entire spectrum, but not uniformly.

Wein's Law - The warmer the radiating body, the shorter will be the wavelength that carries the maximum energy.

Boltzmann's Law - If the temperature of a body is doubled, the energy output is increased 16 times.

UNDERSTANDING C: Radiation becomes less intense with distance.

Unfocused radiation decreases in intensity with increasing distance. As the distance from the sun doubles, the energy density is reduced by one fourth, as it is spread over four times the previous area. The sun pours out energy at a prodigious rate, most of which is lost to empty space. By the time radiation from the sun reaches the earth, it is reduced in intensity to less than a hundred-thousandth of its original strength. This is still sufficient, however, to supply very nearly two calories per square centimeter per minute to the top of the earth's atmosphere. If all the solar energy which fell on a one-square-foot surface in an hour at the top of the atmosphere could be captured, it would be enough to warm a pint of water over 80°F! Venus, closer to the sun, receives energy at the rate of 3.72 calories per square centimeter per minute, while Mars receives but 0.84 calories per square centimeter per minute. Ringed Saturn, lying nearly 10 times farther from the sun than the earth, receives but 0.02 calories per square centimeter per minute.

UNDERSTANDING D: Stars may be classified.

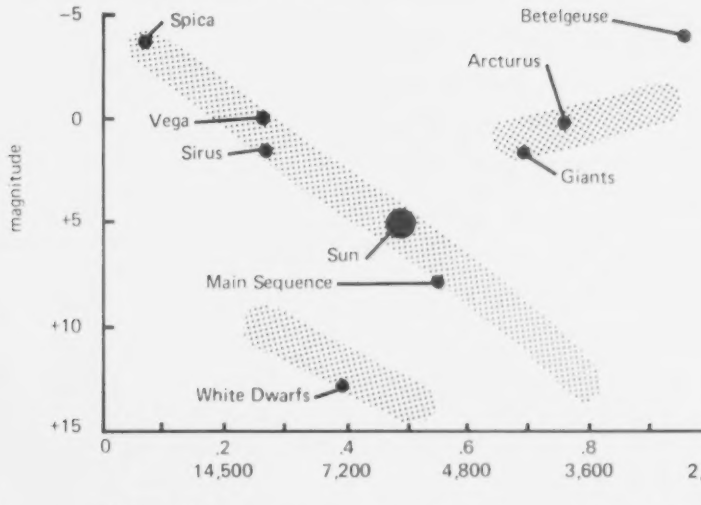
Just as people differ from each other and other organisms, so too stars are different from each other. A system is needed to group stars having similar characteristics into a class, and to define as many classes as necessary.

As we view the stars in the sky, we note that there are differences. Some stars appear bluer, others appear redder. Recognizing the relationship between the color and temperature of a body, we infer that some stars are hotter than others (Wein's law).

We also know that the farther we are from a light source, the weaker it appears to us. The color of the light has not changed, and the power has not changed. The farther we are from a radiation source, the weaker we perceive it, for its energy is more spread out. We experience this effect every time we listen to the radio as we drive out of town. By correcting the amount of light we receive for the distance it has travelled, we can calculate the "absolute magnitude" of a star.

The absolute magnitude and the temperature of a star can be used for a stellar classification system.

The Hertzsprung – Russell Diagram



On this graph the absolute magnitude of several stars are plotted against their surface temperatures. The wavelength carrying the maximum radiant energy for each temperature is also shown. Note the "Main Sequence" of stars extending from the upper left-hand side of the diagram to the lower right-hand side. Most stars fall in this band.

By examining the spectrum of a star, the most energetic wavelength can be found. Using Wein's Law, the temperature of the star may then be deduced. The star's position on the Hertzsprung-Russell diagram can then be located. Most of the stars so plotted lie in a band from the upper left to the lower right, forming the "main sequence". The stars at the upper left of the main sequence are the hottest stars, shining brightly with a blue-white light. At the lower right are the cooler stars, shining a dull red. The "giant stars", at the upper right of the diagram, are cool stars, shining with a reddish color. Because they are so very large, up to 100 times the size of our own sun, they emit a large amount of energy. At the lower left lie the "dwarf" stars, stars that are only a few hundred miles in diameter. While the dwarves have about the same temperature as our own sun, their small size makes them appear very dim. Our own sun lies near the middle of the populous main sequence. As such, it is an "ordinary" star, indeed.

Given the distance of the earth to the sun, it is fortunate that our sun is ordinary. A hotter sun, even of the same size, would broil the earth, while a cooler one would result in a colder earth. A white dwarf, even if the same temperature of our sun, could not supply enough energy to sustain life as we know it on our planet, while a giant star could engulf the earth.

CONCEPT NO. 3: Our sun is a nuclear furnace.

Although our sun is a very ordinary star, it is very special to us because it supplies the earth with light and heat, the energy stream which makes life as we know it possible. It is also close enough to discern its size and shape. We can also observe its surface. Compared to the earth, the sun is huge. Its diameter is 110 times that of earth's, and

"weighs" 330,000 times more than the earth. Comparing the earth to the sun is something like comparing a ping-pong ball to a building the size of an average house.

UNDERSTANDING A: The sun has a structure.

About 99% of the sun is made up of hydrogen and helium, the two lightest gases. The sun's gravity, which keeps the planets in their orbits, also holds the materials of the sun into a ball. The temperature, density and pressure of the solar gases increase as the center of the sun is approached.

The sun rotates on its axis about once every four weeks. But the rotation is not uniform; the polar regions of the sun require about 30 days for each rotation, while the equatorial region takes about 27 days for a rotation.

Studies show that the sun is composed of three major zones, or shells, and an atmosphere. The innermost zone is the core. It extends about a quarter of the way to the visible surface of the sun. Within the core, temperatures are inferred to be about 27 million degrees Fahrenheit, and the density of the gases about 100 times that of water. It is in this region that the sun generates almost all of its energy. Because of the extremely high temperatures, most of the radiation is in the gamma ray region, as shown by Planck's and Wein's laws.

A second shell, completely enclosing the core, extends to within about three quarters of the distance from the center to the visible surface of the sun. In this region, the extreme temperatures and pressures existing in the core drop as the distance from the center of the sun increases. The energy liberated in the core of the sun passes through this shell, primarily by radiation processes. Since the temperatures of the shell drop as the distance from the center decreases, the wavelengths of the most energetic radiation increase from the gamma to the X-ray regions.

The third shell extends from the top of the second shell to the visible surface of the sun, or the photosphere. This region is referred to as the "convective" zone, since convective processes are primarily responsible for carrying the solar energy to the photosphere. As the surface is approached, temperatures and pressures continue to drop to lower values at the photosphere, and the temperature is close to 11,000°F.

The top of the third, or convective zone, is the photosphere, the visible surface of the sun. Seen through a telescope, the photosphere appears as a mosaic; a uniform background covered with bright granules. The granules cover about a third (35%) of the sun's surface. They have an average diameter of about 600 miles, and last about eight minutes. Solar gases rise in the centers of the granules, and spread towards the edges, losing temperature by radiation, and re-enter the sun at the edges. The centers of the granules are brighter than the edges because they are about 350°F warmer. The granules are direct proof of the currents in the convective zone. A quiet sun appears much like a pan of boiling water.

The small dark areas are pores. Larger dark areas are sunspots. Pores and sunspots appear dark because they are some 200°F cooler than the surrounding areas. Sunspots are probably formed by solar magnetic fields which interact with the convection currents. A small sunspot may only last a few days; the largest, with diameters up to 75,000 miles, may persist from two to three months. Attempts have been made to link sunspots with the earth's weather, although the results have been less than convincing. Sunspots originate mostly in the middle solar latitudes and move slowly towards the solar equator. A sunspot in one hemisphere is accompanied by a companion in the opposite hemisphere. The solar surface is also marked by flacula, clouds of calcium that are associated with the sunspots. Solar flares are also a feature of the photosphere. These are jets of solar material that are shot into the solar atmosphere, and appear to be influenced by magnetism.

Above the photosphere is a more or less transparent solar atmosphere, which may be seen during total eclipses. The atmosphere has three distinct layers. The lowest layer is the so-called "reversing" layer. In this layer of cool, rarified gases, selected frequencies of radiation from the photosphere are absorbed and re-radiated at longer frequencies. This gives rise to the "Franhofer Lines" seen in the solar spectrum. Above this sphere lies the Chromosphere, a layer of gas several hundred miles thick that decreases in density and increases in temperature in the outward direction. The chromosphere emits a reddish glow due to the presence of atomic hydrogen. Above the chromosphere lies the Corona. This is a region extending several solar radii into space consisting of extremely rarified gases at very high temperatures.

UNDERSTANDING B: The sun radiates its energy from the photosphere.

As stated in the previous understanding, the sun generates almost all of its energy in its core. The energy is passed from the core and through the radiative zone by radiation

processes. Recalling that the temperature of the core is in the millions of degrees and recalling the radiation laws, the energy is primarily of the gamma type, extremely short-wave radiation that is very lethal to living things. As the radiation works its way through the core and radiation zones, the radiant energy is absorbed by successively cooler temperature gases, and therefore re-radiated at longer wavelengths which are less intense. By the time the radiation has reached the convective zone, it is largely transformed to X-ray radiation. Except in very small doses, this radiation is also destructive to living matter, including humans.

The primary method for energy to pass through the convective zone is by convection processes. Hot gases rise to the surface of the sun. In rising, the gases expand and cool. When the gases arrive at the photosphere, their temperatures have fallen to about 11,000^{o}F, the temperature at which they radiate energy to space. The passing of radiation from the very hot core to the relatively cool photosphere converts it from the very intense, lethal gamma radiation to a more benign radiation. Nearly half of the solar energy lies in the visible band. Human eyes have adapted to see in this brightest portion of the solar spectrum. Some ultraviolet and X-ray radiation is still present in the sunshine that reaches the earth. However, most of this radiation is absorbed in the atmosphere.

UNDERSTANDING C: The sun generates its energy by nuclear fusion.

In a nuclear fusion, atomic particles are united to form a heavier element. By contrast, a nuclear fission is the splitting of a heavy element into simpler elements. Both processes release large amounts of energy.

In the center of the sun, the core, hydrogen gas is burned, or fused, to form helium. Four atoms of hydrogen are combined to produce one atom of helium. In the process, a small amount of mass is left over. This excess mass is converted into energy in accordance with Einstein's equation $E=mc^2$. The fusion process requires extremely high temperatures and pressures, the very conditions which exist in the center of the sun, and other stars. The sun "burns" about four million tons of hydrogen each second. Because of its large supply of hydrogen, the sun will continue to shine as it is for several billion years.

At present, the fission process is used in commercial generating stations, such as Palo Verde. Uranium is split into lighter elements, some of which are intensely radioactive.

The fusion process cannot at present be successfully exploited because no material or method has been developed which is capable of withstanding the required extreme temperatures and pressures required for the fusion process.

UNDERSTANDING D: The sun is self-regulating.

The sun generates a very nearly constant supply of energy, acting as its own thermostat. Nuclear fusion requires certain conditions of temperature and pressure to continue. If energy is produced too rapidly, the center core of the sun becomes warmer. The excess energy is used to expand the size of the sun, a process which cools the core, and slows the energy production. Conversely, if the energy production is too slow, the sun shrinks slightly, warming the core, which increases the rate of energy production. The relationship between the core temperature and rate of energy production ensures the steady production and outflow of solar energy.

It is a happy circumstance that, given our present sun, the earth is just about the right distance away to provide a comfortable environment. If we were closer to the sun, the solar energy we receive would be more intense and the earth would be warmer; if we were further removed, the earth would receive less energy and, so, be colder.

The earth receives energy from the sun, which provides a comfortable average temperature. But because the earth also has a temperature, it radiates heat. Over a period of time, the earth radiates to space exactly as much energy as it receives from the sun, and so maintains its average temperature. Any process which interrupts this energy flow to and from the earth will ultimately change the temperature of the earth, and make it a less desirable place to dwell.

WATER

BACKGROUND

Water is a basic natural resource that is essential to all life. It is the liquid of life for which there is no substitute.

In Arizona, water has influenced the distribution, kinds and number of plants, animals, and humans. Arizona's deserts are prime examples of this relationship. Permanent water provides a gathering place for larger numbers of plants and animals. Away from these water sources, the plant and animal life changes rapidly. Unique species, such as creosote bush, cacti, gila monsters, and kangaroo rats, adapted to the lack of water.

For many centuries, human settlements were concentrated in those areas where water was available on the earth's surface or where rainfall was abundant. This water supply was needed for drinking, cooking, washing, transportation, energy and a good supply of fish, wildlife and crops. As humans learned to move or control water, they broadened the areas in which they could live and the number of people they could support. A brief study of the Hohokams provides an excellent example of the importance of water in early human history.

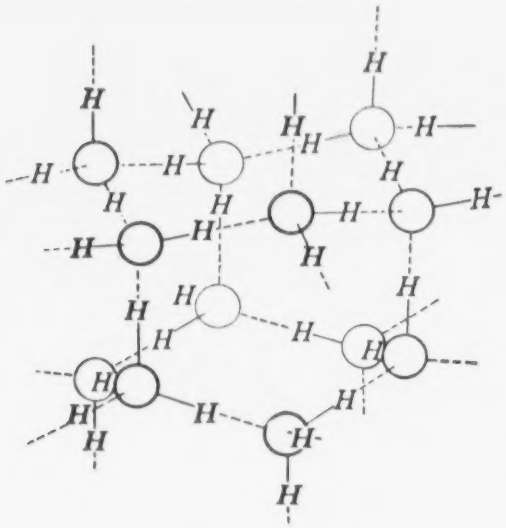
Today, we exert a large amount of control and place increasing demands on the surface and subsurface water. Arizonans have built dams, constructed canals, and sunk wells to put water where they want it and to harness its power to produce energy. Examples of this effort can be studied in the Salt River Project, the Colorado River reclamation projects and in several smaller projects throughout Arizona. Throughout the world, water still plays an important role in our transportation system. Water has become our slave and, unfortunately, we have consistently treated it without proper attention and respect to its importance in our lives.

The concepts and understandings in this chapter are intended to reinforce recognition of water as an ever-continuing necessity in our lives and in the lives of all plants and animals. They will help set the stage for the chapters "Soil" "Plants", and "Animals". Then, in the chapter "Humans in the Environment", you can explore in depth the problems and opportunities we face in our management of this important natural resource.

CONCEPT NO. 1: Water is a naturally occurring compound.

Water is a naturally occurring common liquid that we use daily. We see it as rain, snow, fog, clouds, and ice. We see it in the seas, lakes, streams, springs -- and what comes gushing out of the faucet when we turn it on. Water that we do not see, groundwater, is also of vital importance as the source of much of the water we use.

UNDERSTANDING A: Water is a chemical compound, H_2O, containing two hydrogen atoms and one oxygen atom.



Array of Molecules

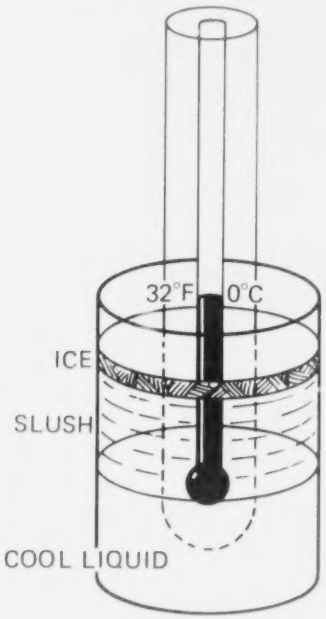
The unique properties of water all depend on the chemical bond which forms the water molecule, H_2O. Each hydrogen atom has room for another electron and the oxygen atom has two unpaired electrons. This mutual need of the three atoms for sharing electrons draws them together and the bond formed is exceptionally strong. This strong chemical bond accounts for water's remarkable ability to adhere to other substances (or "wet" them) and thus eventually to dissolve many of them. It also creates a cohesive attraction between water molecules that gives water a very high surface tension.

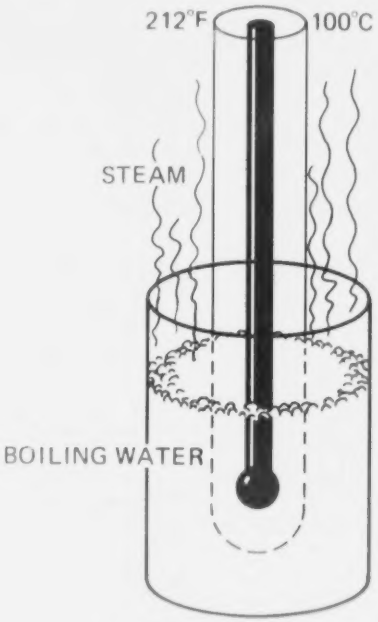
UNDERSTANDING B: Water occurs in three physical forms.

Water is the only substance that appears in three distinct forms of matter within the normal range of earth's climatic conditions. The form it takes depends on the vigor of motion of its molecules. At low temperatures, the molecules move more slowly because they have less energy. This is the condition that produces ice, the solid form of water. At moderate temperatures, when the molecules are activated by extra heat energy, water is liquid. The molecules are close together, yet they slip around freely. This is what gives liquid its flowing motion. At higher temperatures, molecules move about violently, colliding with one another, and form an invisible gas.

Most substances shrink as they get colder until they solidify, but water expands slightly just before it freezes and during the freezing process. Because of this expansion, ice is

lighter than water, whereas almost all other compounds are heavier when frozen. This is fortunate, because if ice were heavier than liquid water, lakes and streams would freeze from the bottom up instead of from the top down. They would become solid ice and in cold climates the deepest layers might not melt even in the summer. Solid freezing would have a disastrous effect on fish and water plants, which could not live through winter.





CONCEPT NO. 2: Earth's water supply is dynamic and renewable.

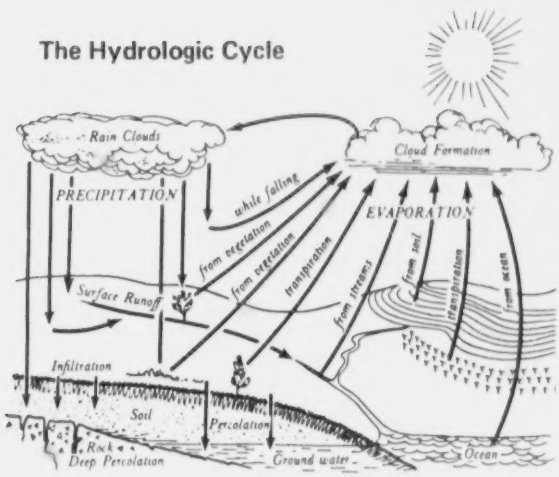
Just as the molecules in water are constantly in motion, the earth's water is continuously moving.

UNDERSTANDING A: Water is distributed and renewed through a water cycle.

The water cycle is one of the largest physical processes occurring on earth. In a simplified illustration, this cycle moves water from the oceans into the atmosphere. It then falls onto the earth's surface. That which falls on the land surface gradually moves back to the oceans.

This large cycle is broken down into many subcycles as the water either falls directly into the oceans or is detained on the land and evaporated into the atmosphere. This water cycle constantly moves water from one place to another.

The Hydrologic Cycle



UNDERSTANDING B: Water plays an important role in other cycles and processes.

As water moves from place to place, it becomes an agent for change because of the large amounts of energy involved. As rain falls, a portion strikes the bare surface of rock and soil. This force breaks away small particles of rock to form soil or moves the soil. Soon the rain gathers into a flowing liquid and carries the rock and soil particles downhill. In "Soil", this process is discussed in greater detail.

While water is on the land, it enters the life processes of plants and animals and, in bodies of water, it is an integral part of the life occurring there. This is explained under concept 4A and in the "Plant" chapter.

UNDERSTANDING C: Water may be used many times.

When water falls on the land as rain or snow and begins its journey toward the ocean, much of the flow is interrupted. It may be used by plants or animals; it may sink into the earth and become groundwater; or it may evaporate. Humans are one of the largest interrupters as they use water in many ways and control its flow for their specific purposes. Water provides many recreation opportunities. The same water we use for recreation can also be used to power hydroelectric plants. Then the water may be diverted to a town or city for home or industrial use or to farmland for irrigation. After home or industrial use, part of the water (now known as sewage) may go back to the river or may be treated and used again. The river may also be used to transport people and/or products from one place to another.

CONCEPT NO. 3: Earth's water is unevenly distributed.

UNDERSTANDING A: Precipitation varies from place to place.

As the primary source for much of the world's fresh water, precipitation is an important part of the water cycle. However, rain and snow do not fall evenly over the earth's surface. One of the major reasons for the differences in precipitation amounts is the

circulation of air masses both globally and in local areas as discussed in the chapter on "Climate".

A study of the average yearly precipitation at different places around the earth shows a high of 460 inches on Kauai, Hawaii, and a low of 1.2 inches at Bataques, Mexico. Even in Arizona, recorded yearly precipitation ranges from an average high of 31 inches at Hawley Lake to a low of 2.47 inches near Yuma. In low rainfall areas, humans are able to live in large numbers by using the groundwater. Pima, Pinal, and Maricopa Counties are examples of locations where humans mine groundwater faster than natural recharge occurs.

UNDERSTANDING B: Water accumulates in different amounts on and in the earth.

More than 97% of the earth's water is found in the oceans. Another 2% of the supply is locked in icecaps and glaciers around the North and South Poles.

This leaves just less than 1% of the water in places where humans, plants and animals generally make use of it. However, this 1% is also scattered in many different locations over, under, and on the earth's surface. It is found in the following locations and amounts:

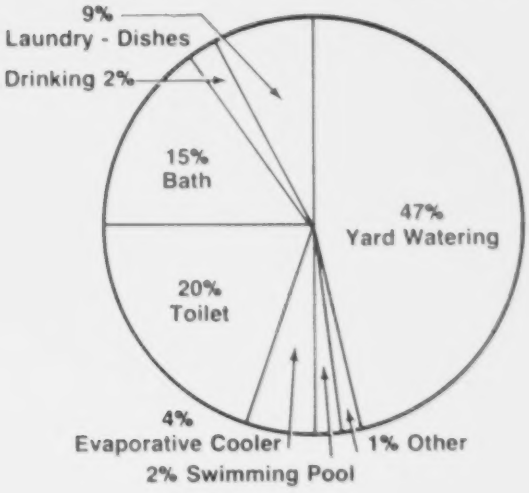
Atmosphere	0.15%
Surface	
Fresh-water lakes	1.40%
Saline lakes and inland seas	1.20%
Average in streams, rivers, etc.	0.01%
Subsurface	
Soil	0.80%
Groundwater within ½ mile of surface	48.00%
Groundwater - deep lying	48.00%

UNDERSTANDING C: Humans redistribute the surface and subsurface water.

We use water for many purposes in homes, businesses, industries, and for growing crops. Across America, the average person uses about 80 gallons of water each day at home for bathing, drinking and eating, flushing the toilet, washing clothes and dishes, and irrigating the yard. The average use by industry is about 70 gallons per day for each of us. Public

use for firefighting, irrigating parks and golf courses, street cleaning, and public buildings takes another 10 gallons a day for each person. Finally, it requires about 1,660 gallons of water per person each day to grow the crops that produce our food and fiber.

ESTIMATED RESIDENTIAL WATER USE

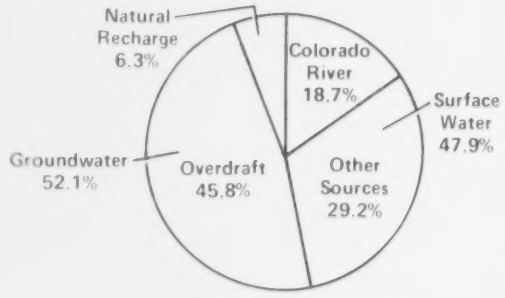


In order to supply this 1,800 gallons for each of us every day, water is taken from lakes and rivers or pumped out of the ground. In Arizona, there are many examples of how humans move water out of the place where it is found naturally and put it where it is needed. The chart below shows the sources from which Arizona got its water supplies and how that water was used. These demands may increase in the future and the chapter "Humans in the Environment" discusses some of the decisions we will face.

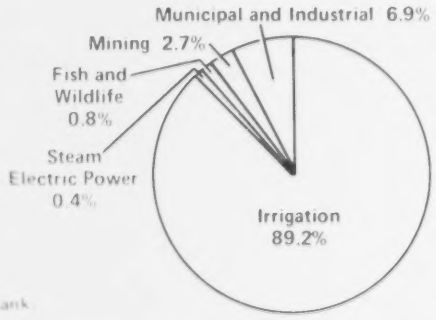
ESTIMATED ANNUAL WATER DEPLETIONS AND SUPPLY SOURCES*

Arizona – Normalized Conditions

Supply Sources	Acre Feet	% of Total
Groundwater	2,500,000	52.1%
Overdraft	2,200,000	45.8
Natural Recharge	300,000	6.3
Surface Water	2,300,000	47.9
Colorado River	900,000	18.7
Other Sources	1,400,000	29.2
Total Sources	4,800,000	100.0%



Depletions	Acre Feet	% of Total
Irrigation	4,294,000	89.2%
Municipal and Industrial	329,000	6.9
Mining	131,000	2.7
Fish and Wildlife	40,000	0.8
Steam-Electric Power	20,000	0.4
Total Depletions	4,814,000	100.0%



*Arizona Statistical Review, 34th Annual Edition, Valley National Bank

CONCEPT NO. 4: Water is vital to all life.

The biosphere that has developed at or near the earth's surface is unique. This human, plant, and animal life exists nowhere else that we know of in our universe. Water is one of the essential ingredients which makes this biosphere possible -- the liquid of life.

UNDERSTANDING A: Living cells depend upon water.

Water is closely linked with all the internal reactions in plants, animals, and humans. It dissolves or suspends nutrients in the soil and carries them into the plant. (See "Plant" chapter on photosynthesis.) The food produced by plants is carried in a water solution to each growing cell in the plants. When animals and humans eat, the food is distributed throughout their bodies in a water solution. Waste products created in animal and human bodies are also carried out of the body in a water solution. Blood, which carries oxygen, contains about 80 percent water.

When water is not available or is in limited quantity, living things suffer and many may eventually die. Some plants and animals have adapted to areas where rainfall is very low. Several of these, such as ocotillo and kangaroo rats, are found in Arizona and provide interesting studies for understanding the importance of water to living things.

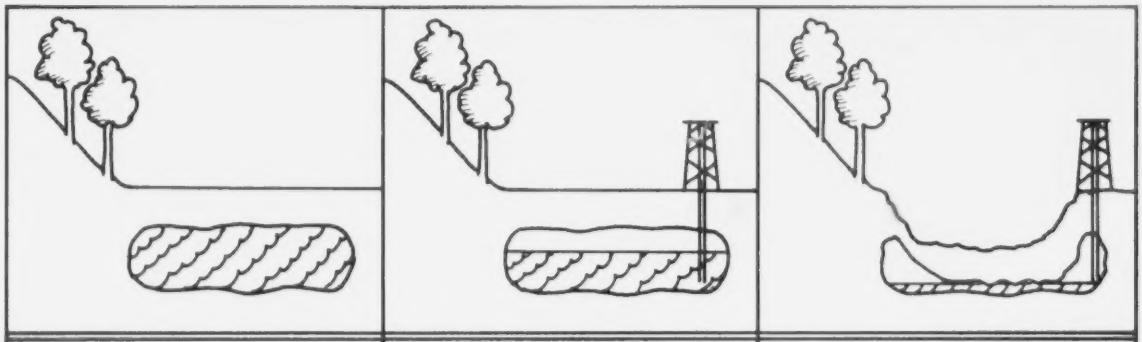
UNDERSTANDING B: Water performs many physical functions.

The properties and distribution of water give it the potential to perform work. Water's impact on the earth's surface illustrates this work in many ways. In the form of moving glacial ice, it carves deep canyons and sculpts mountains.

The energy created by falling raindrops slowly erodes rocks and produces soil. The expansion of water during freezing in cracks also helps to weather rocks. The runoff of water during storms gradually moves the small rock and soil particles downhill. When this runoff reaches the flatter valley bottoms, the soil is deposited to form deeper soils on which most of Arizona's cropland is found. The Grand Canyon is one of the best examples of the power of running water.

Hydroelectric power generated by flowing water is another important product of working water. Dams along the Colorado and Salt Rivers in Arizona are excellent examples of how humans control the flow of water to extend its working life as a power supply.

Another important physical function of water is its role as part of the natural geologic foundation holding up the earth's surface. In Arizona, this effort is evident when we consider the subsidence or dropping of the earth's surface resulting from groundwater withdrawal. Near Eloy, as much as 13 feet of subsidence have been measured over a 30-year period. This is a growing problem in Arizona.



Underground water fills a cavity in the rock layers.	Wells remove water from the cavity creating an empty space in the rock layers.	The weakness created by the empty cavity is no longer strong enough to hold the rock layers pushing down on it. The surface drops. This process is known as subsidence.

Water's importance as a supporting element is also illustrated by the world's transportation system. Oceans, lakes, and rivers serve as major highways to move goods from one place to another. Although airplanes can move materials faster, ships move much larger cargoes at a cheaper cost per unit.

UNDERSTANDING C: Water performs chemical functions.

Given enough time, water can dissolve most substances with which it is in contact. This action allows water to break down rocks chemically as well as physically. This same process explains why water can pick up and carry nutrients for plant photosynthesis and transport food materials in living things.

Some of the chemical reactions in animals and humans which produce different forms of food from simple plant foods would not occur without water. Water also causes the splitting of some phosphate compounds; an important process which releases energy for building other compounds in living things.

33

CONCEPT NO. 5: Water affects and is affected by nature and humans.

As a basic natural resource covering 71 percent of the earth's surface, water plays an important role in all life processes. Concepts 2 and 4 describe some of the basic roles of water. This concept deals with other interactions between water and nature or humans.

UNDERSTANDING A: Water picks up natural and human-made substances as it moves over and through the earth.

The energy expended by rain falling on the earth and water running across the surface is very large. Through these processes, water picks up and carries rocks, soil, plants, and many other objects. The results are both beneficial and destructive. Deep, productive valley soils were formed by this action. However, water is polluted by excessive rates of erosion or by the addition of human-made substances.

The ability of water to dissolve most materials also allows it to move those substances which it dissolves. This action occurs wherever water remains in contact with material for a period of time. Many different salts and other chemicals found in nature are dissolved and moved by surface waters in rivers, streams, or lakes and by water moving through soil or rocks and into groundwater.

Stalactites and stalagmites are examples of water dissolving limestone and then depositing it in another place. We also find that, in some communities, when water evaporates from a glass or other object, it leaves a ring or deposit of salts. These salts have been dissolved and moved by water. This same process results in salt accumulations on or in the soil when water evaporates. Salt deposits in the playa near Willcox and in the soil in the Wellton-Mohawk Valley are examples of this in Arizona.

Pollution resulting from water's ability to pick up or dissolve substances has always been a natural process on earth. The results may be judged good or bad. We must be aware of this action and judge the impact. The chapter "Humans in the Environment" will examine some of these choices.

UNDERSTANDING B: Water affects temperatures.

Water's heat capacity, the ability to store heat without becoming extremely hot, is the highest of all substances in nature except ammonia. This capacity enables the oceans and other large bodies of water to be huge reservoirs of solar warmth. The oceans

particularly keep the earth's weather from going to great extremes of either heat or cold. This can be easily seen by comparing the yearly or daily temperature extremes of the southern California coast with those of the Arizona desert. For example, San Diego's temperature often varies about 10 degrees in a 24-hour period while Phoenix's may vary 40 degrees.

Groundwater also gains and stores heat. It tends to become warmer with depth in response to what is called a geothermal gradient. The temperature to which groundwater is heated also varies from place to place. This results from variations in the earth's temperature in response to geologic condition.

In some places, none in Arizona, the groundwater becomes hot enough to produce steam. By tapping this source with wells, as has been done south of Mexicali, it is possible to generate electricity with the steam. In Arizona, certain irrigation wells and springs produce water too hot to touch. A deep oil test near Tucson found water temperatures at 12,000 feet below the surface to be close to 300° F (water boils at sea level at 212° F). Naturally hot waters could be used for many purposes. Systematic study of Arizona's geothermal waters has just begun.

An important benefit of water's heat capacity, to industry and residents of hot climates, is the cooling effect. When water is placed in contact with hot materials, as in the cooling system of a car engine, it absorbs heat and reduces the overall temperature of the system. This heat is then dissipated into the air, as in the radiator of a car or in a pond next to an industrial plant.

In the evaporative cooling used in many homes, we use this process to cool the air. The hot air outside is drawn through wet materials and the water absorbs the heat. The cooler but more humid air is then forced into the building and cools the interior. This form of cooling requires less energy and is becoming more popular in the Phoenix area as energy prices increase.

UNDERSTANDING C: Water quality affects usage and usage affects quality.

Water quality changes are caused by many things. In general, the change in quality results when something is added to or removed from the water. These things include natural as well as man-made products. They may result from the dumping of waste materials, natural or accelerated erosion, leaching of deposited materials, or a change in water movement.

Many examples of the effects of water quality changes occur in Arizona. Around our lake systems throughout the state, it is possible to record the rate of sedimentation and, often, its effect on aquatic life. Below the dams, where cooler water is released, a change in the habitat often occurs that again affects the aquatic life found there.

Humans learn more each year about the good and bad effects of water use and management on water quality. Fluorides in water may reduce cavities but too much causes mottling of teeth. Sewage effluent is unusable in its raw form, but when treated, the liquid and solid by-products are beneficial. The chapter, "Humans in the Environment", deals with some of the choices we face in water use and quality control and their impacts on our use of this liquid of life.

THINGS GEOLOGIC

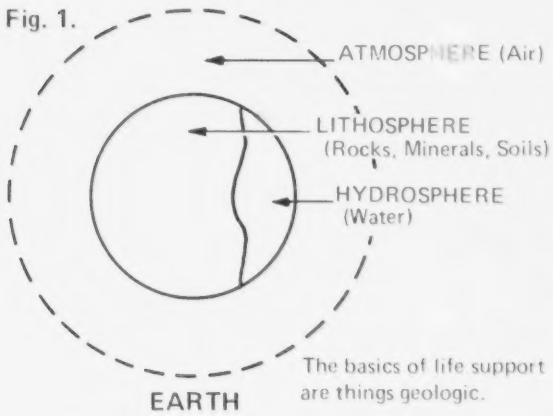
BACKGROUND

The expression "things geologic" in contrast to "geology", is used because it permits discussion of things, such as a car, that, although they are not geology per se, are nevertheless geologically related. Thus, it affords flexibility in the development of ideas, principles, concepts, and relationships that exist between the non-living and living worlds.

Life - all life - is fundamentally dependent upon and influenced by non-life, by things geologic. Some of these, such as the sun, water, air, and soil are so important that they are given separate emphasis elsewhere. However, they should be recognized as being a part of a continuum of non-living things - things geologic - that, in various combinations, are vital to all life.

This earth, the home of all known life forms, is a thing geologic made up of things geologic. Humans, and all other living things (the entire biosphere), live by utilizing, for the most part, an inherited condition or environment, acquired over a length of time - difficult not only to comprehend, but to appreciate. Living things utilize non-living resources that are the result of a history that geologists believe exceeds 4 billion years in length.

Fig. 1.



The basics of life support are things geologic.

The non-living (abiotic) earth consists of gases (atmosphere), liquid (hydrosphere), and solids (lithosphere). These, in various combinations and ways, are involved in a myriad of physical and chemical processes. A process may be judged constructive, destructive, or both, depending upon perspective and point of view. The eruption of Mount St. Helens was destructive in many ways - but over time, will have had results that could be judged as having been constructive. Time and place influence judgments. Geologically, such things are merely change. Will Durant, philosopher, has written: "Civilizations exist by geological consent - subject to change without notice." Many geologic resources and earth characteristics are the result of yesteryear's catastrophic events. The earth itself was born in unimaginable violence.

The abiotic part of the earth most familiar to us is the lithosphere, or the rocks and minerals (earth-materials) part. Rocks are constructed from minerals, and minerals, in turn, from elements or combinations of elements.

It will be noted that the emphasis here is not on routine identifications and definitions. Rather, it is on larger ecological principles that are "rooted" in earth materials - the controls that these non-living phenomena exert on the living. By governing their habitats, things geologic rule over plant and animal life. We know that continents and oceans have changed through time and that life, through change and adaptation, has accommodated in order to survive and grow in diversity.

Four fundamental attributes should be emphasized as being inherent in the word geologic: (1) great lengths of time compared to human history, (2) finiteness, non-renewability, depletability, or limitation of non-living mineral and energy resources, (3) inequality in the distribution of essential earth materials, and (4) most of the earth and its contents (upon which we have increasingly become dependent) are out of sight below the surface upon which humans live. Much contemporary concern (political, economic, environmental, ecological), though generally unrecognized, can be traced to one or more of these four general attributes.

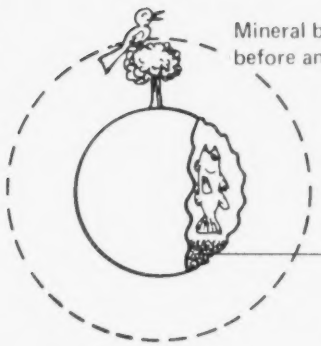
The great human experiment involves our capacity to live, grow, learn, and manage within the poorly understood limits and conditions imposed by the earth's natural inheritance of things geologic. There are no guarantees to the future.

CONCEPT NO. 1: Life is dependent upon, and influenced by, things geologic.

UNDERSTANDING A: The order of appearance on earth of the three kingdoms of matter, from first (oldest) to last (youngest), was (1) MINERAL (things geologic), (2) VEGETABLE, (3) ANIMAL.

Things geologic must exist before life can exist. Because this is the way it is in nature, it isn't difficult to teach this fact-of-life. A bird in the tree and the tree in the "ground" is a useful example that can be easily embellished to make the point.

Fig. 2.



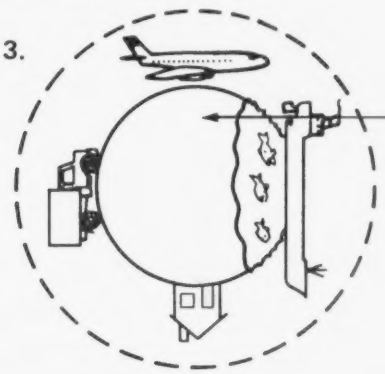
UNDERSTANDING B: Early life was supported by a favorable combination of things geologic, including conditions, substances and processes.

Tolerable physical-chemical conditions, lands and seas, and vital physical and chemical processes, preceded first life. Reactions between water, air, and minerals released essential elements and compounds for redistribution and use by early plant life.

UNDERSTANDING C: Things geologic are a fundamental part of the life-support system that make all living things, including people and their civilizations, possible.

It is well known that civilizations often build over the remains of others. Subsequent civilizations have been more populous than the preceding, a fact made possible by the interaction between technology and geologic resources. There have never been more people on earth than there are at present (1.6 billion in the year 1900; 4.2 billion in the year 1978; future?)

Fig. 3.



Source of energy (coal, petroleum, uranium, geothermal), all metals from area (iron, copper, lead, zinc, gold, etc.), and industrial minerals or nonmetals (clay, limestone, sand and gravel, building stone, gypsum, salt, many chemicals of phosphorous, potassium, sodium, lithium, boron, magnesium, etc., etc., etc.)

Requirements for Material Things = Things Geologic
(Can't Make Something Out of Nothing!)

UNDERSTANDING D: Animal and plant varieties are geologically controlled through habitat diversity.

Because of its fundamental geologic diversity, Arizona has more plant and animal species than most other states.

CONCEPT NO. 2: All life forms must adapt to an inherited, complex geologic condition - or perish.

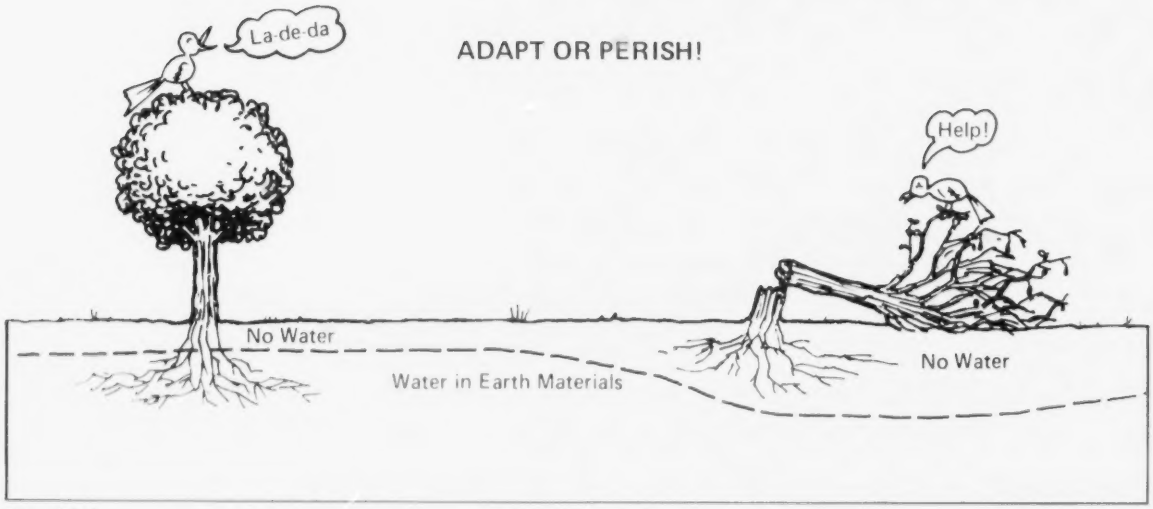


Fig. 4(a)

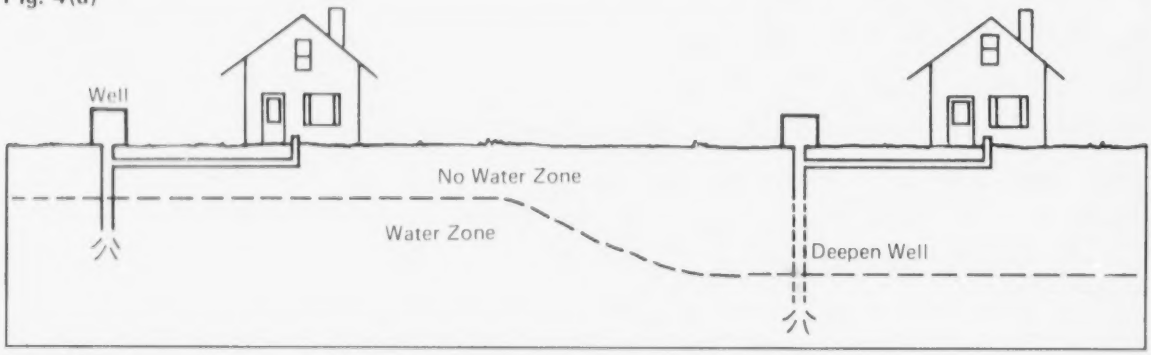


Fig. 4(b)

Water – Ice is mineral – A Geologic Commodity

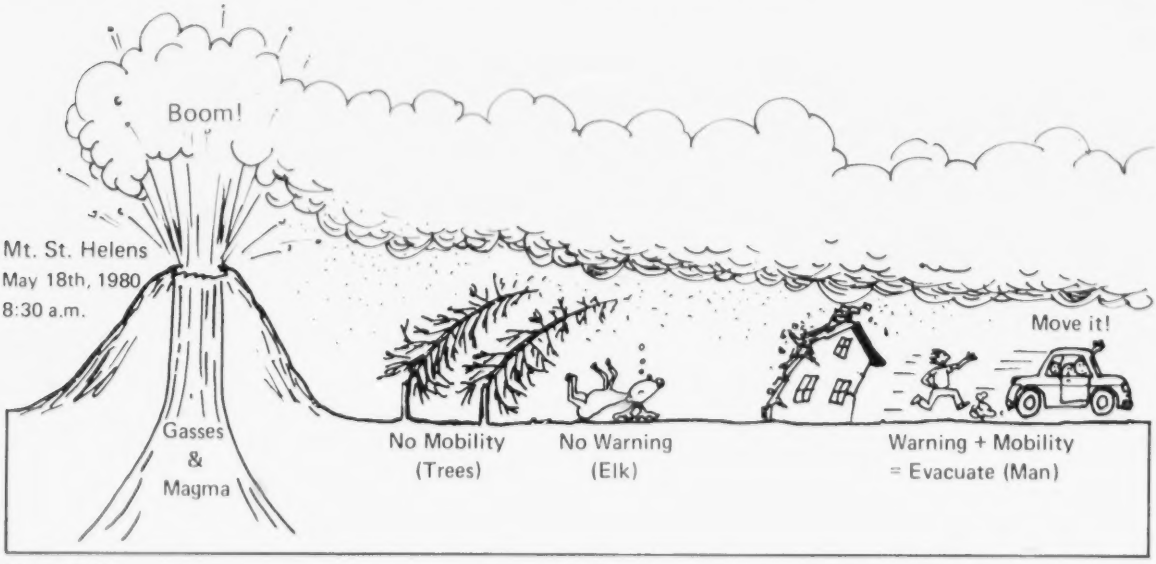


Fig. 4(c) "Civilizations exist by geologic consent, subject to change without notice." *(Will Durant)*

The fossil record in rocks clearly demonstrates the naturalness of extinction. The dinosaurs are the most vivid example.

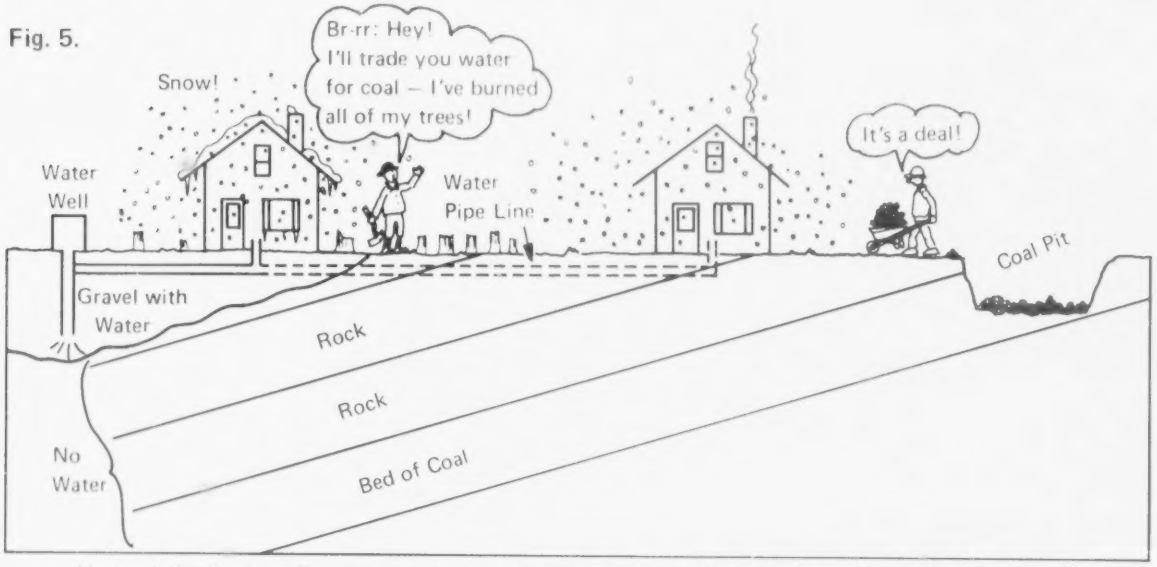
UNDERSTANDING A: Most geologists believe that the earth has been developing for more than 4 billion years.

Much of the evidence for this comes from studies of moon rocks and meteorites. On earth, natural processes (erosion, metamorphism, etc.) have either removed or changed the once very oldest rocks. The oldest rocks known in Arizona are considered to be just less than 2 billion years in age.

UNDERSTANDING B: No two places on earth are geologically identical.

The earth differs greatly from place to place in its geologic characteristics. As an example, nations are not equally endowed with earth resources; therefore, they either acquire by trade, purchase, or war, the resources to meet their perceived needs or accept the consequences. The inequality in distribution of important geologic resources is a constant source of conflict in world affairs.

Fig. 5.



Unequal distribution of resources requires either cooperation or conflict in order to get needs together.

UNDERSTANDING C: There is only one "crop" of most geologic (minerals, fuels) resources.

Because many geologic resources are very old and fixed in their places of origin, they are frequently thought of as being finite, nonrenewable, depletable, or otherwise limited in supply. Although this idea is being expressed more frequently, it should not be viewed as inevitably leading to an early doomsday.

Rather, economic factors should signal the need to anticipate change long before a state of serious shortage arises. This is to say that gradual change is more likely (and desirable) than instantaneous change and attendant chaos. However, the latter can be brought about by international confrontations that disrupt vital supply lines.

CONCEPT NO. 3: Earth materials (rocks, minerals and associated phenomena such as ores, petroleum, etc.) "grow" in, and are products of, contrasting geologic environments.

It follows from the above that if a region's geologic history is devoid of a particular geologic environment, then the products normally associated with that environment cannot be present. Geologic environments are interpreted from geologic maps. The better the maps, the better will be the interpretations of resource potential.

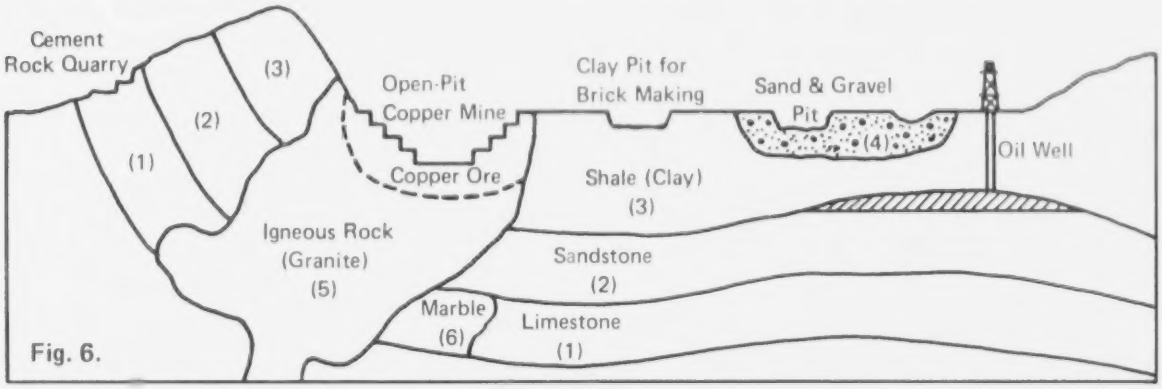


Fig. 6.

Sedimentary Rock = (1), (2), (3), (4) (Sources of brick, cement, petroleum, sand and gravel)
Igneous Rock = (5) (Reason for copper deposit, making of marble)
Metamorphic Rock = (6) (Heat from igneous rock changed limestones)
Relative Rock Ages: Oldest to left – (1) – (2) – (3) – (5) + (6) – (4)

Geologic Environments Control Rock Types and Associated Minerals

Trees and water and animals are renewable resources if properly used. However, there is only one "crop" of minerals and they can be "renewed" only by discovery.

UNDERSTANDING A: The three fundamental rock-types, IGNEOUS, SEDIMENTARY, AND METAMORPHIC, are created by processes that operate within contrasting geologic environments.

Rocks are made of smaller units called minerals. Thus, the nature of a rock is controlled by its mineral composition and arrangement. Igneous rocks form from the cooling of molten material either within the earth or at its surface; sedimentary rocks are deposited on or very near the earth's surface; metamorphic rocks form by the changing of other rocks under the influence of heat and/or pressure at depth.

UNDERSTANDING B: Rocks always consist of particles of one or more essential minerals - the so-called "rock-making" minerals.

Rocks also contain accessory minerals unimportant in classification or assigning of rock names. As an example, the essential minerals in a granite are orthoclase feldspar and quartz. Mica and other minerals present in small amounts in many granites are accessory.

UNDERSTANDING C: Most ore (metallic) minerals are not rock-making minerals - they do not enter into rock classification.

Although the ore minerals form deposits in rocks, they are not themselves, rock. Ore minerals make up the rare and unusual ore deposits (copper, gold, silver, lead, zinc, molybdenum, chromium, tin, platinum, uranium, etc.) that have become so useful to modern civilizations.

UNDERSTANDING D: Earth materials are of many different ages - they are products of processes and conditions that prevailed at different times and places at or below the earth's surface.

Earth history is "read" from the great diversity of rocks and minerals and their arrangements. It is the job of geologists to probe the earth for its tightly held secrets.

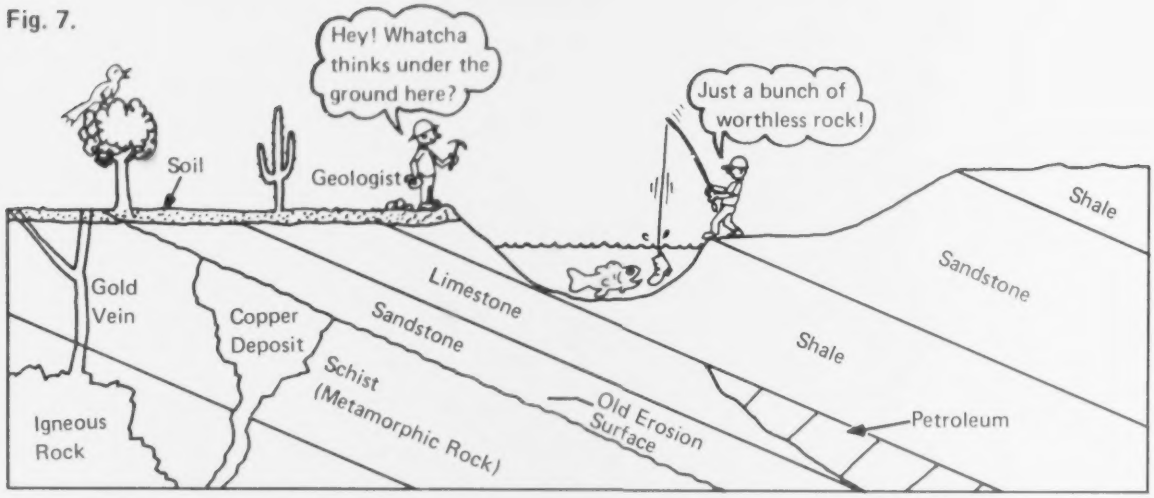
CONCEPT NO. 4: Although humans live at the earth's surface, they have become dependent in large measure upon depletable geologic resources beneath it.

UNDERSTANDING A: Discovery is required before new resources can be developed and utilized.

Petroleum exploration often probes to depths exceeding twenty-five thousand feet.

The easy-to-find deposits and occurrences of many important geologic resources have, for the most part, already been discovered - only the more difficult and costly remain to be found.

Fig. 7.



Trees and water and animals are renewable resources if properly used. However, there is only one "crop" of minerals and they can be "renewed" only by discovery.

UNDERSTANDING B: Serious conflicts between nations are often "rooted" in things geologic. (See figure No. 7)

Our present civilization is strongly influenced by what is below the surface of many countries. The most widely publicized example has been petroleum in the middle eastern countries.

UNDERSTANDING C: Earth materials cannot be found and removed from the earth without some disruption of the natural condition.

Although modern civilizations must continue to exploit the earth for things geologic, efforts are underway to learn to do it with as little permanent distortion of other important values as possible.

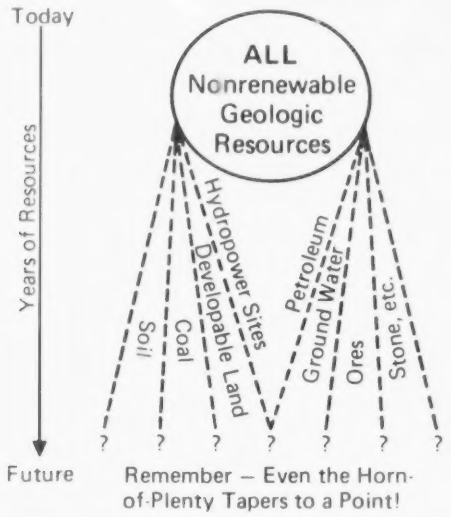
UNDERSTANDING D: "Land" should be viewed as having depth - it is not merely the surface.

How deep is the land we call Arizona? Answer: the radius of the earth.

CONCEPT NO. 5: The point of ultimate depletion of essential attainable earth materials is unknown.

It is true that there is only so much of all aspects of the non-living earth. These are the nonrenewable resources that are said to be finite. To what extent is exhaustibility a real problem? Who knows? (See figure No. 8)

Fig. 8.



UNDERSTANDING A: Extraction and processing of earth materials is an ongoing activity essential to the growth and continuance of all the world's industrial societies regardless of political structure.

Sustained yields of geologic resources are possible only by combining: (1) continued discovery with (2) conservation (recycling, alternative materials, use less, etc.)

UNDERSTANDING B: Nations are becoming increasingly interdependent with regard to supplies of essential earth-materials resources.

Though seldom stated, World War II was, for the most part, a mineral and energy resources war on the part of Germany, Italy, and Japan. Prior to that time, the world's mineral resources were dominated largely by Great Britain and the United States. The East-West problem includes long-ranging concerns over the control of future sources of vital earth materials (petroleum is the most obvious of contemporary interest).

UNDERSTANDING C: The destiny of the world's community of people, which is expanding, is closely linked to the ability of people to discover, understand, manage and share things geologic.

Resource competition is growing between East and West, and things geologic are at the heart of many of the major geopolitical questions of the day. Reconciliation of such problems would seem to demand public recognition as a precondition. Yet, there seems little effort to acquaint the general world citizenry with this growing concern. Resources shortage is a common enemy over time - it threatens all. Will it be sooner or later? Awareness and resulting actions are the only weapons we have of accommodating this fact. On a lesser scale, resource aspects are important to individual communities, whether town, city, country, state, etc. In Arizona, the geologic resource that presently

generates the most concern is groundwater. It, too, is out of sight, and therefore relatively unknown in quantity and quality. It is easy for the public to assume there will always "be enough".

UNDERSTANDING D: Comprehending the earth is an ever-increasing challenge to mankind - there are no automatic guarantees to a successful future.

We are a part of an on-going human experiment, an experiment in how to manage ourselves on a limited earth. We can become more ecologically aware in an attempt to counter the tendency for mankind to become just another aimlessly wandering herd, incapable of sustaining itself with some semblance of dignity.

Awareness counters being taken by surprise. Awareness can lead to anticipation of future problems and, in the case of pending serious resource shortages (energy etc.), can provide transition time sufficient to offset chaos.

Awareness of the role that things geologic play in sustaining the biosphere, of which we are a part, is fundamental to sound ecological understanding and responsible planning.

SOIL

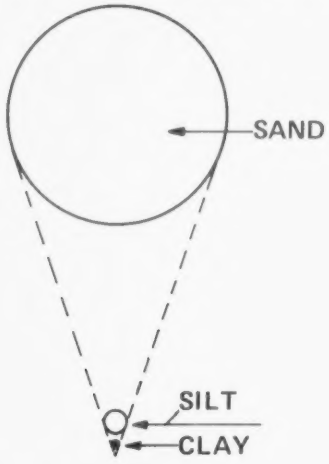
BACKGROUND

Soils, an earth material, form one of the basic ecological links between the non-living, "things geologic", and many living organisms in the biosphere.

They are produced from the breakdown of rocks into very small particles and provide the medium in which large quantities of plants grow.

Every soil contains soil materials, organic matter, living organisms, water and air in various amounts.

For the purpose of this Guide, we will use the USDA, Soil Conservation Service's definition of soil materials. They say that any earth material that passes through a number 10 sieve is a soil material. These materials are classified as sand (.05 to 2 mm), silt (.002 to .05 mm), and clay (less than .002 mm).



THE RELATIVE SIZE OF SAND, SILT, AND CLAY

Soil is essential to many forms of life. It is the foothold for the food, fiber and feed crops we grow. In many places, it provides support for our buildings and roads. It cleanses and holds water. It absorbs heat from the sun and radiates this heat at night.

Soils form a thin mantle over much of the land surface of the earth. It's produced from the action of climate and living matter acting upon the rocks. Time and topography also affect the final product.

Soil is related to the earth much as the skin is related to an apple. The earth's soil is far less uniform than the skin of an apple. It is deep in some places, shallow in others and absent usually on steep, rocky outcrops and mountain peaks, and in the lands of perpetual ice and snow. It may be red, as soils are near St. Johns, or it may be yellow, as they are near Yuma, Arizona. It may be sandy or it may be clayey.

In Arizona, more than 300 different soil types have been identified. Each soil has different physical characteristics of color, depth, texture, horizon depths, structure and consistency. As a result of these, each soil performs a little differently under the same kind of use by humans. They also have different capabilities in growing native plants or crops.

As humans developed, they learned to plant seeds in the soil and to care for the plants as they grew. In Arizona's Salt River Valley, the Hohokam Indians built and operated major irrigation systems from before the time of Christ until about 1200 A.D. It was the evidence of this system which caught the attention of European settlers in the 1880s. From their efforts to use the same combination of soils and water to produce food, today's Salt River Project grew.

As we used soils more intensively to grow plants, to build on, and to construct small dams, we discovered that soils are different, and that it is easy to reduce the productive capability of the soil.

As early as 60 A.D., the Romans had several good manuals for farmers. Columella's "Husbandry" was a handbook for 15 generations. Some of his suggestions were good, even in the light of modern knowledge. He discussed amounts of fertilizer and organic matter to be used, timing of farming operations, and application of combinations of practices (tillage, crop residue use, and crop rotations) to various kinds of soil.

With the fall of the Roman Empire, much of this written knowledge disappeared. The people of Europe were disorganized and lived in a dark age of disease, famine and war for more than a thousand years. Then, in the beginning of the 18th century, attempts were again made to rationalize farming and to improve soil management. A complete discussion of the history of soil husbandry can be found in "SOIL", the 1957 Yearbook of Agriculture.

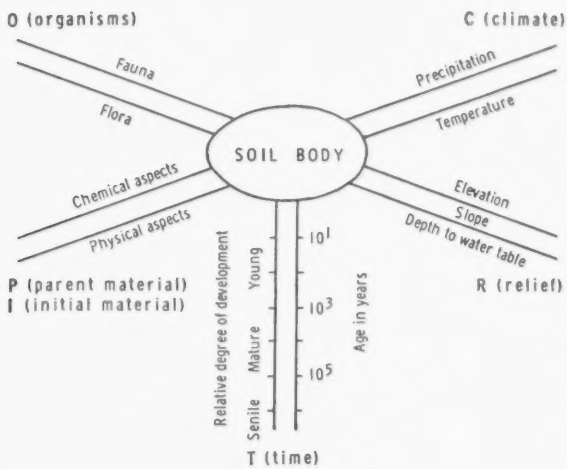
Looking back on this history of the soil's use, we arrive at a conclusion about the importance of soil to humankind. As we look at the present, it is important to realize that we still abuse and misuse the soil. We spend tremendous amounts of energy producing food and fiber from the soil, but continue to allow excessive erosion of this important natural resource. We can prevent a significant part of this waste and reduce the cost of protecting the soil.

50

To accomplish this, we must understand soil and its limitations and capabilities. The concepts and understandings presented in this chapter are an important step in reaching this understanding.

CONCEPT NO. 1: Natural processes form soils slowly at or near the top of the earth's crust.

Soil formation proceeds in steps and stages, none of which is distinct. These steps and stages are like the overlapping fibers in a piece of string--the eye can hardly tell where one fiber ends and another begins. These processes began with the formation of the Earth and will continue as long as the Earth exists. The two major processes in the initial development of soils are weathering, to produce small particles, and accumulation or deposition, to produce a body of soil. Residual soils are those that accumulate in place by the weathering of bedrock. Particles produced by weathering are often moved to places of deposition or accumulation and these are transported soils. All such loose accumulations of particles are subject to continuous internal change and modification. Soils can be thought of as being youthful, mature, etc. The two major steps in the formation of soils are accumulation of soil materials and differentiation of horizons in the profile. The five major factors in soil formation are parent rocks, topography, time, climate, and living organisms.



UNDERSTANDING A: Soil particles come from the breakdown of rocks.

Mechanical and chemical weathering acts on the solid and massive rocks of the earth's crust to produce particles; sand, silt and clay. Freezing and thawing are examples of mechanical weathering. The reactions produced by water and air in contact with the rock minerals are examples of chemical weathering.

UNDERSTANDING B: Time is a major factor in creating soils.

Weathering actions began when the first rock was exposed to breakdown processes. These actions, though slow, continuously form new soil particles. This happens both to rocks at the surface of the earth and to rocks below the soil mantle. Generally, the longer soil materials stay in one place, the deeper and more developed (mature) the soil becomes.

UNDERSTANDING C: Climatic factors affect the formation of soils.

Precipitation, temperature, wind, and sunlight are the major climatic factors affecting soil formation. Heating and cooling, freezing and thawing, wetting and drying all tend to weaken the rock structure. Areas with low rainfall would tend to produce soil material more slowly than areas with high rainfall. Where temperatures vary widely from daytime to nighttime, rocks tend to crumble more rapidly.

The climate also affects the amount of life which occurs on a soil's surface and the rate at which these living organisms breakdown following their death. In warm, humid climates, large amounts of plants and animals are produced and breakdown moderately fast. In cool, humid areas, fairly large numbers of living things exist but their breakdown following death is slower. In hot, dry areas, small numbers of living things exist. Here, their breakdown is rapid when in the soil, because of both loss of water and the heating or burning that occurs.

UNDERSTANDING D: The transportation and accumulation of soil material creates transported soils and influences soil formation and location.

Both climatic and geologic events of the past and present strongly influence soils. Floods, earthquakes, and volcanos rapidly change the placement of rocks, soil material, and soil. Other past events, such as uplifting or folding, created our topography which speeds or slows down the movement of soil material.

Wind erodes soils with poor plant cover and moves the soil material from one location to another. As the wind velocity decreases, the soil particles fall to the earth creating a new layer of soil materials. In windy areas, this process usually results in dunes or piles of uniform soil materials.

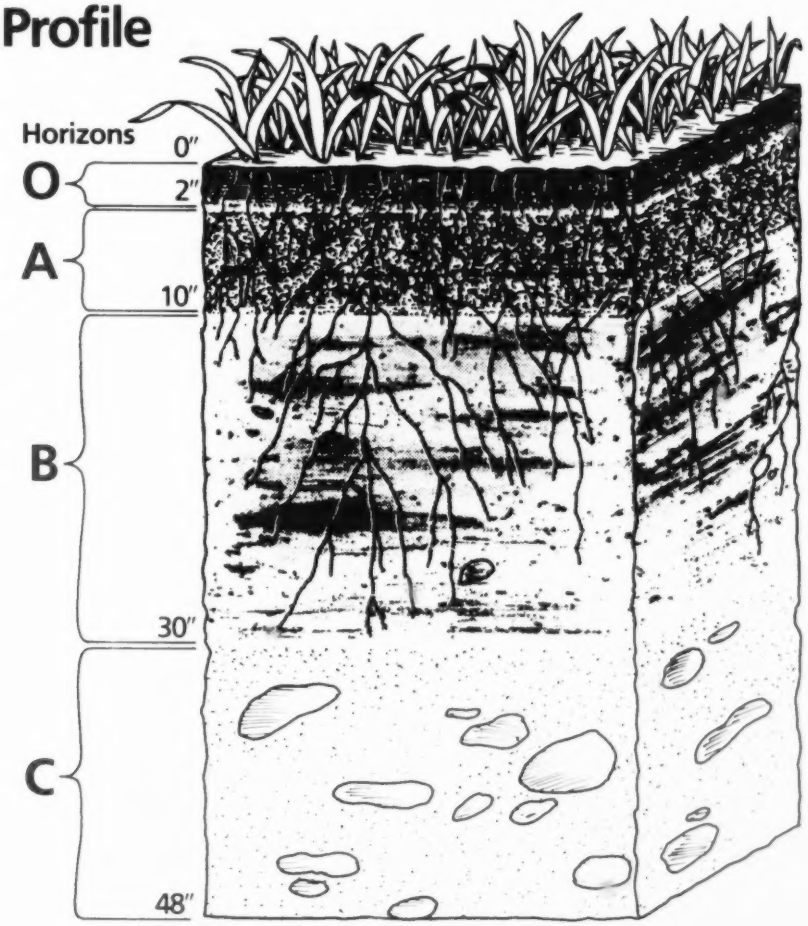
Water erosion performs a larger role in soil formation and change than does wind erosion. Soil particles and parent material are continuously carried downhill in water by the pull of gravity. This process has resulted in the deep deposits of transported soils in all but the most recently formed or steep valleys. It was this carrying in and depositing that formed the basis for the rich arable soil in the Salt River Valley. This same process in the Nile Valley of Egypt has allowed the continuous farming of transported soil in that area for several thousands of years. However, we must recognize that excessive erosion by either wind or water can also deplete soil.

Soil movement by geologic or erosive forces has also created the unequal distribution of soils. Areas with deep, fertile soils in river valleys have formed at the expense of higher, mountainous areas where little or very shallow soils are found. This is part of the reason that certain areas exist where humans can produce crops easily and many other areas are not tillable.

CONCEPT NO. 2: Soils have individual profiles which distinguish them from other soils.

As the weathering processes continue over a period of time and under varying climatic conditions, each soil gradually acquires its own unique character. This is seen by soil scientists in the development and differentiation of horizons or layers within the soil profile. These changes affect the color, structure, texture, consistency, porosity and other physical and chemical properties of the soil and of each horizon. They result in the individual profile which each soil has.

A Soil Profile



UNDERSTANDING A: Soil is made up of many components.

Soil contains many particles and components. These include sand, silt, clay, minerals, organic matter, plant and animal life, air, and water. The various amounts of each of these components and the amount of weathering helps determine each soil's character.

The plants and animals are mainly the unfamiliar organisms of the soil--worms, grubs, moles, bacteria, and molds. Although the organisms do not sound pleasant, they are important in the natural process of decomposing organic materials and preparing the soil for future plant growth.

Approximately one-third of the volume of soil is open space for air, water and dissolved minerals. The soil must contain air and water for plant growth.

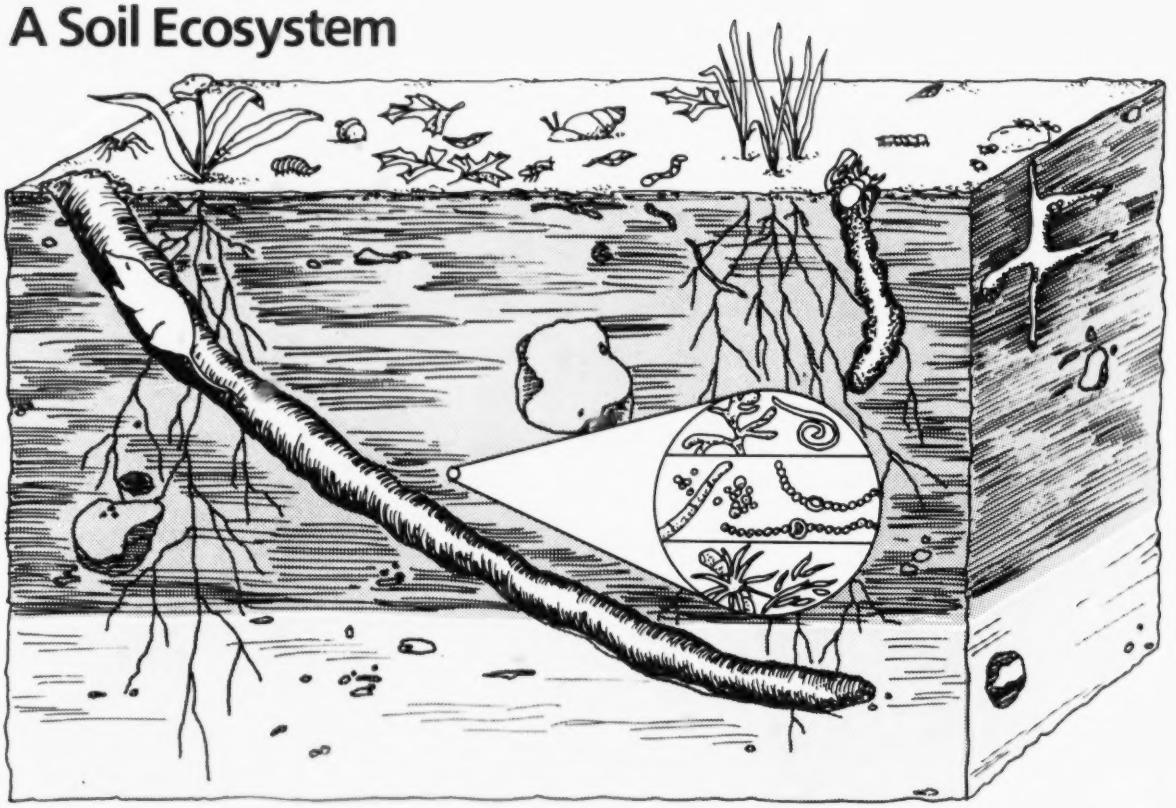
UNDERSTANDING B: The types of rock from which soil material is formed influences the type of soil formed.

Soil materials form from any kind of geologic material. Soils formed from shales tend to be high in silt and clay with a low resistance to water and wind erosion. Sandstones produce sandy soils with lower available water capacity but with greater resistance to erosion. Other geologic materials impart their characteristics to the soil being formed. As soils get older and are more weathered, the influence of the original rock becomes less distinct.

UNDERSTANDING C: Plants and animals are active factors in soil formation.

Plant roots grow down into the soil. They break up the soil and the parent rocks, rearrange soil particles, force openings into the soil, and make the soil more porous. They bring plant nutrients from the lower layers to the upper layers. Plants and animals die and decompose, making a surface layer higher in organic matter. Animals burrow in the soil and mix it. Earthworms, bacteria and fungi live in the soil, feed on the organic matter, and recycle plant nutrients. The organic matter in the soil comes from the decay of dead plants and animals. It provides food for animal organisms in the soil and nutrients for plant growth. In those areas where many living organisms grow, this influence is greater than in areas where less life exists.

A Soil Ecosystem



Because water does run off the surface of steeper soils, this limits the amount of water that can sink into the soil for plant growth. A good permanent plant cover decreases the runoff by slowing the water down and giving it time to infiltrate.

UNDERSTANDING D: Soils have temperature and moisture regimes that affect their characteristics.

Although the climatic conditions in which a soil occurs strongly influences its temperature and moisture regimes, its topographic position also affects these.

Soil temperatures below 20 inches remain within fixed ranges during the year and determine the soil's temperature regime. Very cold or very hot soils limit plant growth because of their effects on root development and seed germination.

The moisture regime is a measure of the percentage of the year that the upper 16 inches of the soil profile are wet. Wetter soils are usually those with a high watertable. This restricts root development and adversely affects human-made structures placed in the

soil. Except for special crops like cranberries, farmers drain these wet soils in order to cultivate them.

CONCEPT NO. 3: Soils have definite capabilities and limitations.

Each soil's physical and chemical properties create characteristics which determine how that soil will respond to our use of it. Soil scientists map the soils by these properties and can then predict these responses. Soils that are deep, almost level and have high available water capacities can be grouped together as prime farmland. They require only a minimum of conservation efforts to control erosion and produce high yields of locally adapted crops. Soils that are sloping, shallow or have a low available water capacity are difficult to farm. They require a maximum conservation effort in order to produce minimum levels of crop yields.

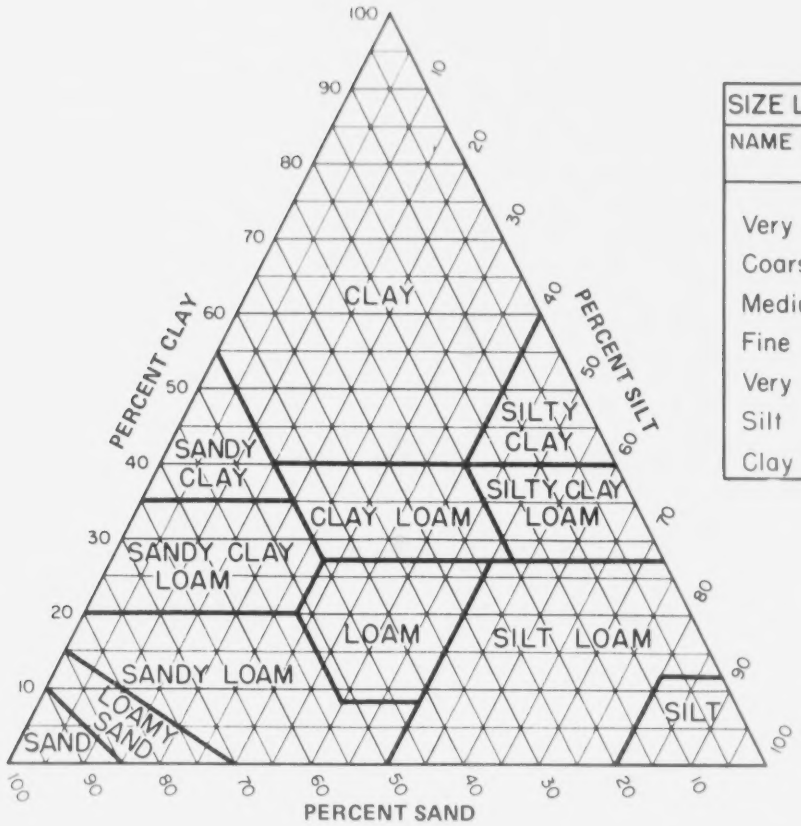
UNDERSTANDING A: Soil texture determines many of a soil's characteristics.

Soil texture is a product of the varying amounts of clay, silt and sand found in the soil. The presence of rock particles modifies the texture but does not change it, except over very long periods of time.

Different soil textures have different available water capacities. This is the amount of water a soil can hold that is available to plants. Water moves into and through finer-textured soils more slowly than a soil which is coarser textured.

Fine-textured soils, clays and clay loams, swell when wet and shrink while drying. This causes cracking on the soil surface. With some types of clay, the shrink-swell movement is great enough to crack foundations or roadbeds built on the soil.

SOIL TEXTURAL CLASSES



SIZE LIMITS OF SOIL SEPARATES	
NAME OF SEPARATE	DIAMETER (range)
	MILLIMETERS
Very coarse sand	2.0 - 1.0
Coarse sand	1.0 - .5
Medium sand	.5 - .25
Fine sand	.25 - .10
Very fine sand	.10 - .05
Silt	.05 - .002
Clay	Below .002

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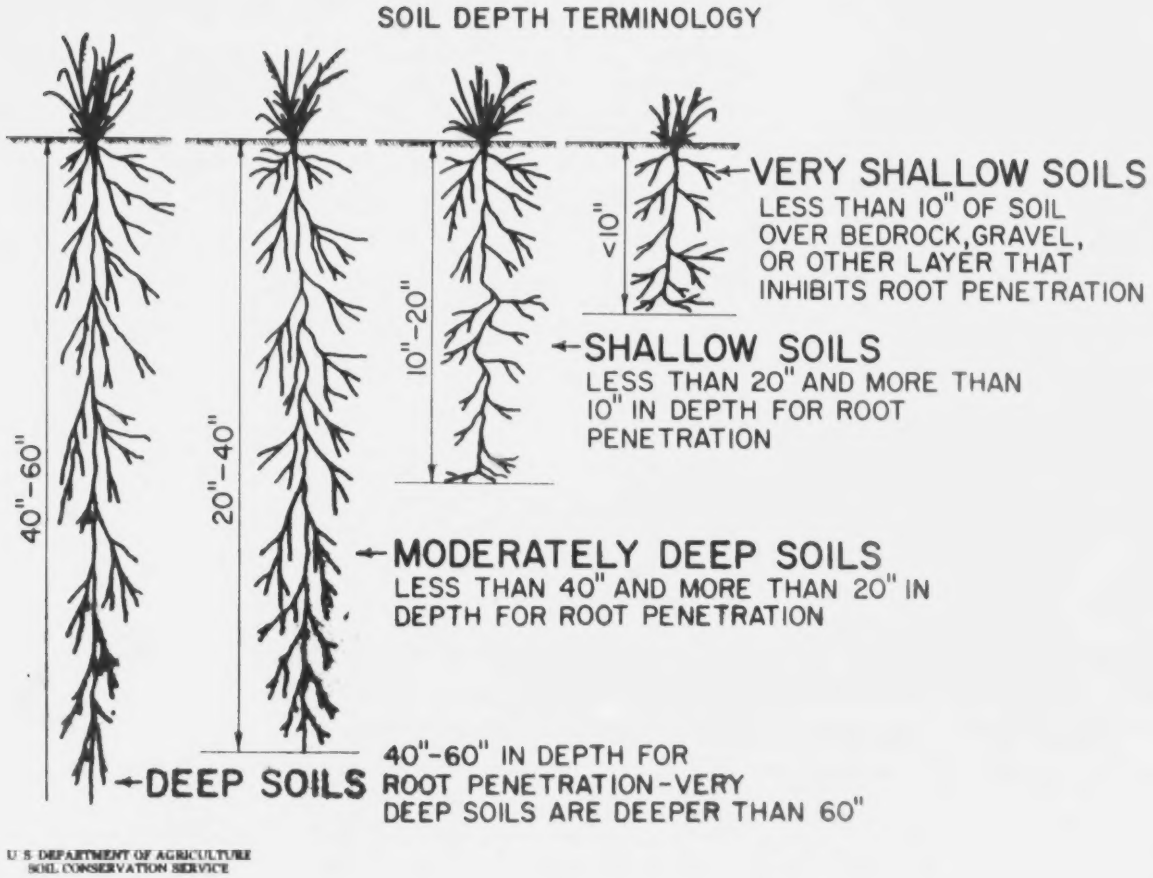
UNDERSTANDING B: The soil's depth affects its ability to perform.

Soils are underlain by bedrock, small rock particles, soil material or accumulations of chemical compounds which have been leached out of the topsoil. Calcium carbonate or caliche is one example of these materials. The illustration shows how scientists classify a soil's depth and emphasizes the fact that soil mapping is generally restricted to the top five feet of the earth's surface.


SOIL DEPTH TERMINOLOGY
VERY SHALLOW SOILS
LESS THAN 10" OF SOIL OVER BEDROCK, GRAVEL, OR OTHER LAYER THAT INHIBITS ROOT PENETRATION
<10"
SHALLOW SOILS
LESS THAN 20" AND MORE THAN 10" IN DEPTH FOR ROOT PENETRATION
10"-20"
MODERATELY DEEP SOILS
LESS THAN 40" AND MORE THAN 20" IN DEPTH FOR ROOT PENETRATION
20"-40"
DEEP SOILS
40"-60" IN DEPTH FOR ROOT PENETRATION-VERY DEEP SOILS ARE DEEPER THAN 60"
40"-60"
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Deep soils hold more water than shallow soils of similar texture and have more room for root development. Therefore, it is easier for people to grow plants in deep soils.

Building homes or laying water and electric lines in areas with shallow soils is more expensive because the foundation or trench must be excavated into the material under the soil. This rock material is harder to dig than is soil.

UNDERSTANDING C: Sloping soils have limitations for many uses.

Scientists map the slopes of soil surfaces and classify them into the following groups: 0-1% - level or nearly level; 1-3% - gently sloping, 3-8% - sloping; 8-15% - moderately steep, 15-50% - steep; 50%+ - very steep. Frequently, soils with slopes above 5% also are shallower soils because of erosion. This erosion problem is one of the reasons that steeper soils have limitations, especially for cultivation or other intensive uses which may increase the rate of erosion.

CONCEPT NO. 4: Soils play important roles in many natural cycles.

As students progress in their understanding of the Earth and its environments, they will look at many of these natural cycles. Some of them are very simple and others are extremely complex. The understandings for this concept present only a few of the roles which soils play in these cycles. As the teacher, you may wish to explore other cycles and discuss the soil's role.

UNDERSTANDING A: Soil regulates water movement and is a cleanser of water.

In the hydrologic cycle (see Water Chapter), a certain amount of the precipitation which falls on the earth infiltrates directly into the soil. Some water moves downhill in streams and rivers and a portion of this gradually sinks into the soil in the riverbed. Downstream, farmers may impound the water behind dams built of soil or other earth materials and then irrigate with it. In all cases, the soil texture and condition have a direct influence on the rate and amount of water which moves into and through the soil.

As water moves through the soil, the soil particles and organic matter act as a strainer. Materials suspended in the water are removed and the water is cleaned. Chemicals absorbed in the water may also be removed if the water is held in the soil and then evaporated or transpired by plants. Many disease organisms carried by water are unable to live in the soil and die when water is held there.

Water may then be removed from the soil or the geologic material below it by people or plants. It may also rise to the surface further downstream as a spring.

UNDERSTANDING B: Soil organisms break down organic matter that is created by or results from food cycles.

Much of the waste materials created by animals and some of the effluent created by humans is deposited on the soil. In addition, dead plants or parts of plants, animals and humans return to the soil. Then, the decay process carried out by soil organisms begins and the organic matter is converted to nutrients for plant growth. This same process may be studied in greater complexity in food, carbon, and nitrogen cycles.

UNDERSTANDING C: The life cycle of many plants and animals and of humans takes place almost entirely in or on the soil.

Many plants depend on soil for support and as a source of water and minerals from which they manufacture food. This plant food provides a major portion of the diet for many animals and for humans. We also harvest plants for other purposes.

Soil animals live their entire lives within the soil. Many other animals burrow or dig their homes into the soil or on its surface. Humans use the soil to support buildings, roads, recreation areas and other items that create our lifestyle.

UNDERSTANDING D: Soil stores heat energy from the sun and releases it slowly as part of our solar energy cycle.

A certain portion (approximately 20%) of the sun's radiation which reaches the Earth's surface is absorbed by the soil and stored as heat. As the air temperature cools, the soil radiates this heat and helps to reduce extreme temperature variations.

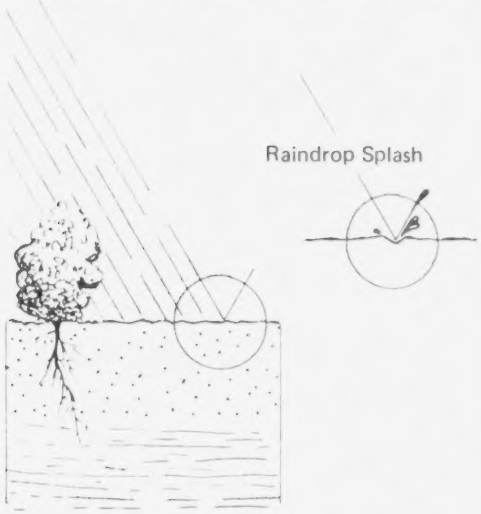
CONCEPT NO. 5: Soil loss or deterioration frequently exceeds nature's ability to replace or cleanse it.

UNDERSTANDING A: Accelerated erosion by wind or water causes increased soil loss.

When plant cover is removed from the soil, usually by our activities, the rate of erosion increases. Under these circumstances, the formation of new soil is slower and the erosion becomes a harmful rather than beneficial action. As soil material is moved, it frequently becomes a serious water or air pollutant. When this material is deposited, it damages structures or land or reduces reservoir capacities.

There are four stages of water erosion as illustrated below. Splash erosion is perhaps the most severe because it loosens and spreads soil particles which can then be readily carried by runoff or wind.

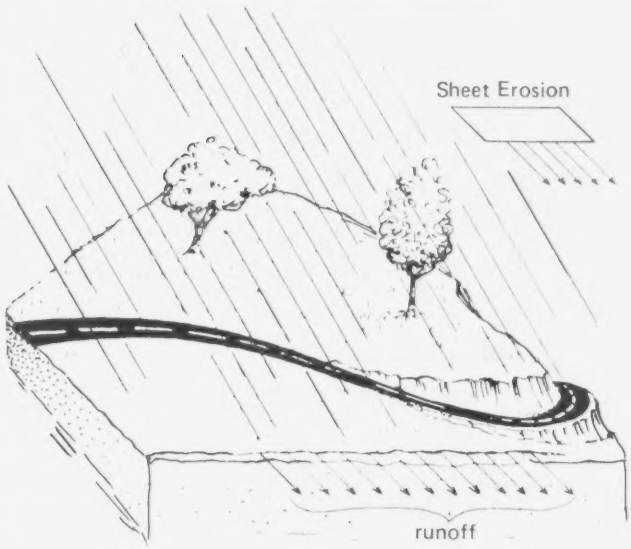
No. 1 Stage of Soil Erosion by Water



Rain falling on bare soil surface loosens soil particles.

Millions of raindrops contain enough energy to disturb a considerable amount of soil that washes away in erosion, Stage No. 2.

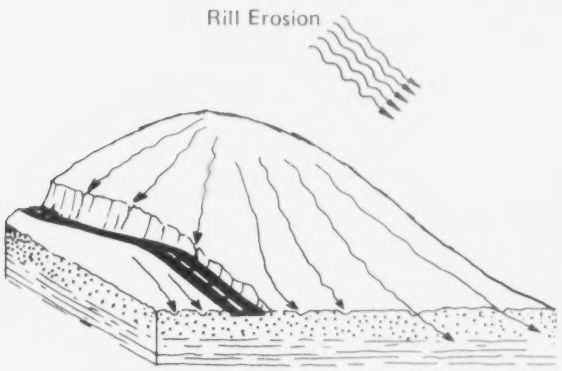
No. 2 Stage of Soil Erosion by Water



Water from rain, snow, hail, irrigation, or flooding flows across the soil in a layer or sheet.

It carries away soil too!

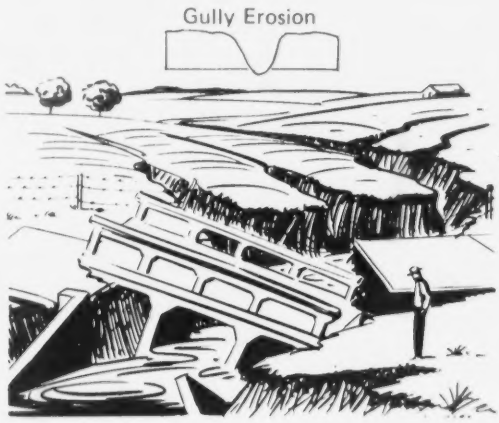
No. 3 Stage of Soil Erosion by Water



Small streams of water form, wash away soil, and leave small gullies.

Note rill erosion on hillside, flatland, and road cuts.

No. 4 Stage of Soil Erosion by Water



If erosion is not checked by vegetation or structures, gullies form, land and everything on it may be damaged or destroyed.

UNDERSTANDING B: Salts and other chemical compounds, either naturally occurring or human-made, may accumulate in the soil too fast. This can decrease the soil's productivity and/or cause water pollution.

Salt deposits and chemical compounds, such as sodium chloride and calcium carbonate, occur naturally in our soil and water. Under certain climatic conditions, particularly low rainfall and high evapo-transpiration (see Plant Section), these materials accumulate in the soil faster than nature can redistribute them. Unless we take some action to reverse this process, the soil becomes less capable of growing plants.

We increase these accumulations of salt by irrigating cropland. The addition of even low-salt water to a high evapo-transpiration setting will gradually increase the salt content of the soil. This salt may then be leached from the soil by excess water and carried into the groundwater. Development of salt-tolerant crops and proper irrigation methods helps reduce the severity of this problem.

Finally, humans use chemicals to control both plant growth and insects. When applied without proper controls, these chemicals upset the soil's productivity and may pollute water through the leaching or erosion process. This same problem occurs when we dispose of chemicals in uncontrolled dumps.

Nature is often unable to cleanse soils that have been polluted in these ways.

PLANTS

BACKGROUND

As mentioned in the chapter on "Things Geologic", the three kingdoms in order of their appearance on earth were MINERAL, PLANT, and ANIMAL. Current scientific theory suggests that plants have existed for at least half of the earth's history. Earliest plants inhabited aquatic environments; but as plants gradually increased in diversity, they alsc adapted to terrestrial habitats until today, they are found in practically every habitat on earth. Plants existed before animals and provided essential parts of the habitat for animals to develop. Many plants have developed a relationship which is conversely dependent upon animals. Most plant life developed without animals, but animals cannot survive without plants. Some plants are dependent on animals for distribution and reproduction. Birds distribute mistletoe; the yucca moth pollinates the yucca flower.

Plants are divided into green and non-green plants, and both have essential functions in the earth's ecosystem. Green plants provide the basic link between the sun's energy and the food required for the survival of animals. Non-green plants are essential agents in the decay of organic matter. All green and non-green plants are renewable, providing animals with a continuous source of food and shelter provided the proper environment for plant growth continues to exist.

In Arizona, the great diversity of geologic and climatic conditions supports a variety of plant life which is paralleled by a diverse animal life that is not equalled anywhere in North America. These biotic communities of Arizona have been studied by naturalists from all parts of the world. A field trip from Yuma to the San Francisco Peaks above Flagstaff will encounter plants and animals that are typical of desert to sub-arctic regions. In many places in Arizona, the distance separating these extreme environments is less than 100 miles.

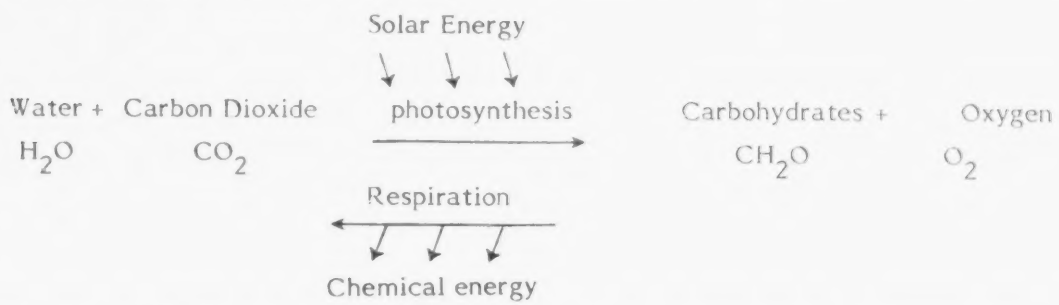
Man in very basic ways is no less dependent upon the diversity of plant life than any other animal. Man has learned to domesticate and improve plants to provide his basic needs. Man and all other animals will continue to be dependent on the earth's plant life. Therefore, any environmental impact that significantly changes plant life will have an impact upon the animal world, man's world, our life-style, and perhaps our existence.

CONCEPT NO. I: Plants are vital to living things.

Green plants provide the vital link between the sun and life on earth by producing food and energy for other plant and animal life. Plants provide essential needs for other living things, such as oxygen, water and shelter. Plants help to cycle these and other important components of the atmosphere and earth. Plants must continue to grow and flourish as renewable natural resources if other life is to exist.

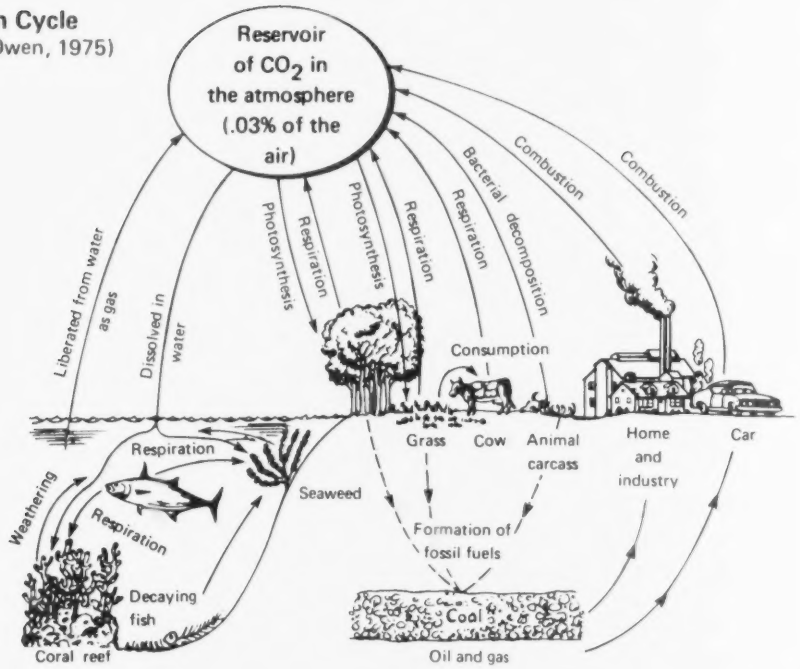
UNDERSTANDING A: Only green plants can use the sun's energy to produce food through photosynthesis.

Photosynthesis is the process by which green plants in the presence of chlorophyll, and using the sun's energy, convert water (H_2O) and carbon dioxide (CO_2) into carbohydrates and oxygen (O). The reverse of this process is called respiration whereby both plants and animals utilize carbohydrates and oxygen to produce water, carbon dioxide and chemical energy. Plants respire in darkness, whereas animals respire continuously. The equation for this reversible process is as follows:



These two processes are intimately involved in the carbon cycle. Chloroplasts, self-contained photosynthetic units within plant cells, contain green chlorophyll. Chlorophyll gives plants their green color, and if plants lack this green color, as fungi and molds do, they are incapable of manufacturing their own food. Deciduous trees and shrubs loose their green leaves temporarily in the wintertime, become dormant, and decrease food production. Evergreen plants, such as pines and firs, carry out photosynthesis all year long. The saguaro and palo verde trees of Arizona have green trunks, where this process is carried out. In fact, all of the cacti carry out photosynthesis in their "stems" and the spines are modified leaves - an adaptation for survival in an arid climate.

Fig. 1. Carbon Cycle
(from Owen, 1975)



Plants manufacture oxygen, carbohydrates, sugar and protein for life giving essentials to animal survival. Green plants use less than 1% of the solar energy reaching the earth (36 billion calories per acre during ten hours of sunshine). The majority of this solar energy is absorbed by the oceans, soil and rocks, or reflected back into the atmosphere. Approximately 70% of the earth's photosynthetic processes occur in the oceans where phytoplankton produce a major source of the earth's oxygen supply.* Phytoplankton is essential in large quantities for existence of aquatic life in the seas. Except for a few simple organisms, living animals from the amoeba to the great blue whale depend on photosynthesis for survival. Before there were photosynthetic plants on earth, the atmosphere was probably devoid of free oxygen.

UNDERSTANDING B: Non-green plants are important agents of decomposition.

Non-green plants, e.g., fungi, molds and bacteria, cannot produce their own food due to a lack of chlorophyll. They are nevertheless important to the life cycle because they decompose organic materials. The top layer of one acre of fertile soil one foot deep may contain about 1,000 pounds of bacteria and 1,200 pound of fungi and molds. These plants secure their energy and carbon from organic residues. The nutrients released by this

* Owens, 1975

66

decomposition are the natural fertilizers that are made available to growing plants. Man has learned to "hasten" this process by covering dead plant materials with a layer of soil and keeping this compost moist to enhance the growth of molds and bacteria. A considerable amount of heat is given off during the process of decay. Man has also learned to make and use artificial chemical fertilizers to provide "plant food" for cultivated croplands and gardens when soils become nutrient deficient.

UNDERSTANDING C: Plants are an important part of many natural cycles.

The most important cycle involving plants and animals is the FOOD CYCLE, also referred to as the energy cycle (Figure 2). As plants grow and reproduce, they are consumed by animals. Both plants and animals eventually die and decompose. Decomposition breaks down tissues into their basic elements which are picked up by new plants for growth and reproduction, and the cycle begins again. This natural cycle is perhaps the most easily observed and readily explained. There are other natural cycles intricately involved with this cycle which are not so obvious. The more important ones involving plants are the seasonal cycle, mineral cycle, nitrogen cycle, hydrologic (water) cycle and carbon cycle.

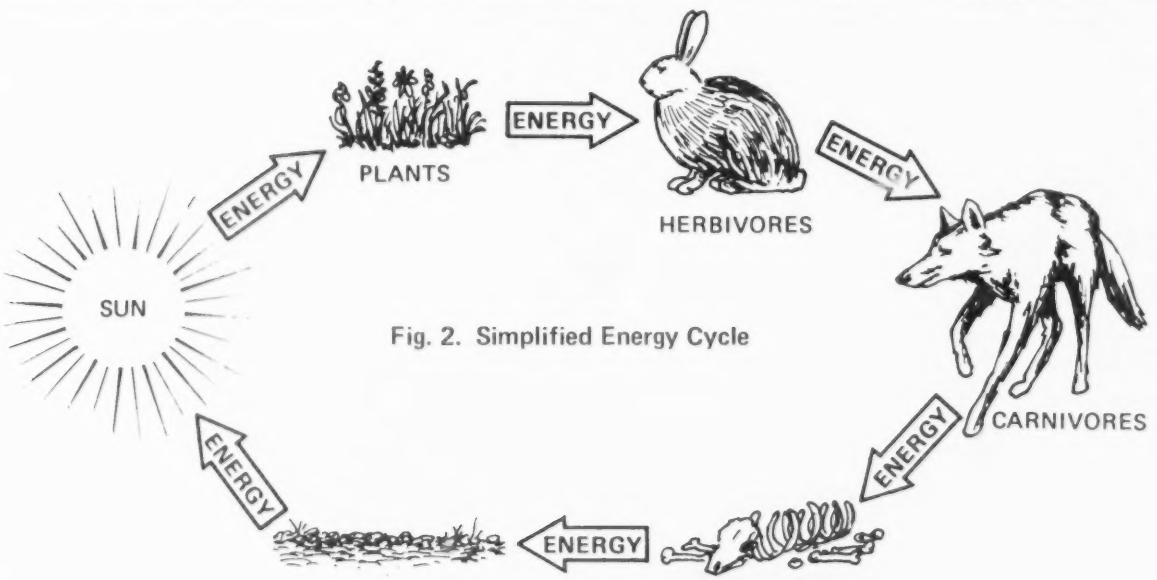


Fig. 2. Simplified Energy Cycle

The SEASONAL CYCLE usually begins in the spring when plants begin life as seeds in the ground or as new growth on dormant perennial plants. The springtime flush of growth is the most active time of year for plants and animals. Most plants mature in the summer, and bear fruit and seeds in the fall before the winter dormant season.

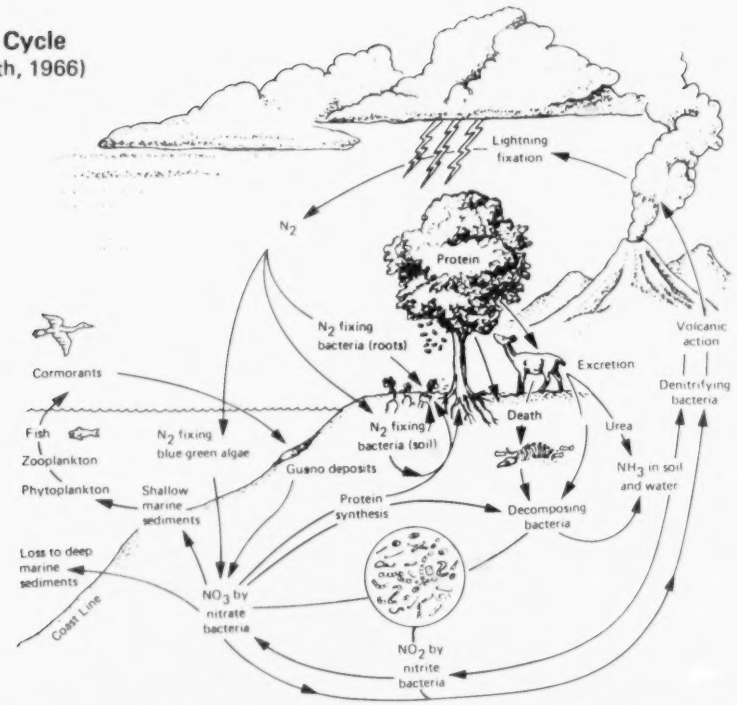
The annual seasonal cycles are not so obvious in the deserts of Southern Arizona as in the northern states. Many desert plants which grow in the winter are similar to plants which grow further north in the summertime. Arizona plant life is unique in that some plants are "cool season" growing in the cool winter months of spring, and others are "warm season" growing in the summer months. These plants can, therefore, produce good forage for wildlife and livestock throughout the entire year.

All plants have a growing season and a dormant season in the natural environment. Perennial plants have a dormant period when growth slows or stops; annual plants die at the end of a growing season and remain dormant as seeds. Each plant's life cycle is closely tied to the seasonal cycle, which is controlled by external factors such as climate and length of day. These will be discussed in greater detail in the next concept.

The MINERAL CYCLE is closely tied to the life cycle. As plants develop, they take up existing minerals from the soil. When plants and animals die and decompose, the minerals from their tissues are returned to the soil. Of approximately 92 elements which occur naturally in the environment, 35 to 40 are required by plants and animals. Plants acquire these important minerals from the soil when they absorb water through their roots. After oxygen, hydrogen and carbon, the most important elements to plant life are nitrogen, potassium, phosphorus, calcium, sulfur, magnesium and iron, in that order. Important trace elements include boron, copper, manganese, molybdenum and zinc. Elements of lesser importance include sodium, chlorine, cobalt and iodine. The lack or imbalance of any one of these minerals will limit plant growth. Some minerals vary in their importance to plant type and, as we know from diet studies, certain plants are more important to animals primarily for their mineral content.

The NITROGEN CYCLE (Figure 3) is important to animals as a constituent of protein. Neither plants nor animals are able to utilize free nitrogen directly as it exists in the atmosphere or soil. Various species of soil bacteria and some algae have the ability to convert free nitrogen in the air to nitrites and amino acids, the essential components of proteins. A comparison of the four most important elements to plant life (as shown in a corn plant) indicates the relative amounts of these elements: carbon, hydrogen, oxygen and nitrogen. Nitrogen is far more abundant in air (78%) than it is in the plant (1%). It is, however, an essential element in the manufacture of protein.

Fig. 3. Nitrogen Cycle
(from Smith, 1966)

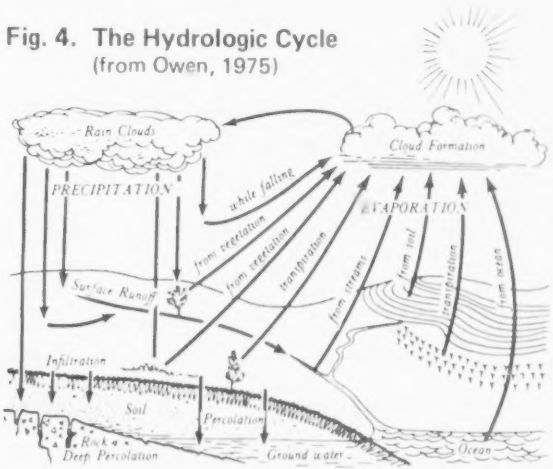


Plants are significant in the CARBON CYCLE by utilizing CO_2 (carbon dioxide) in the air to produce carbohydrates through the process of photosynthesis. These carbohydrates are stored in the plant as a reserve source of energy for the plant's growth and the ultimate energy source for animals. As shown in the discussion of photosynthesis, animals burn some of this energy and return carbon to the air as CO_2 during the process of respiration. The remainder of the carbon in the animal's body tissues will eventually return to earth through the decomposition process where it becomes a part of the soil. When plant products (wood and coal) are burned, energy in the form of heat is produced, and the carbon compounds in the plant are released into the air through the process of combustion.

	In AIR	In CORN PLANT
Carbon	Less than 1% (as CO_2)	9%
Hydrogen	Less than 1%	10%
Oxygen	21%	80%
Nitrogen	78%	Less than 1%

Plants have two important functions in the WATER (HYDROLOGIC) CYCLE (see Figure 4): 1) transpiration, and 2) regulation of run-off. By the process of transpiration, a lawn or large tree can release 100s of gallons of moisture into the air each day through billions of stomata (pores in the leaves). There has been much concern in Arizona that too much water is "wasted" by large trees growing along irrigation canals, rivers and streams. Cacti transpire very little water into the air, and thereby conserve a scarce commodity.

Fig. 4. The Hydrologic Cycle
(from Owen, 1975)



Soil and water retention is another important function of plants. The amount of run-off from a given slope can be greatly affected by the species of plants growing there. Run-off measured on the Beaver Creek experimental study area south of Flagstaff increased by 30 percent when the watershed was converted from brush and trees to a grassland. Non-deciduous trees and shrubs transpire water more or less continuously into the atmosphere, especially during the growing season, whereas grasses and deciduous plants become dormant part of the year. Moisture which is not used directly by plants runs off into streams and rivers or sinks into the soil and becomes a part of the underground water supply. Grass roots can also filter the water and prevent soil erosion, thereby improving the quality of the water downstream. Thus, the kinds of plants growing over a large area or along a stream can have a very profound effect on the water cycle. As indicated here, man can also influence the water cycle by changing the plant life in a given area. Perhaps the greatest alteration of the water cycle has occurred in the deserts of Arizona where water from huge dams on the larger rivers is used to irrigate croplands on formerly arid desert land. By irrigating thousands of acres of crops, especially cotton and alfalfa, transpiration is increased tremendously over that which occurred when only desert plants existed. In areas where irrigation water is pumped from the underground water table, we have increased the transpiration of this water faster than it can be replaced. Thus, we see that although man cannot stop the water cycle, he can through the manipulation of plant life and by other means alter the water cycle dramatically. Arizona is the first state to pass a law that will eventually require the pumping of water from underground to balance the recharge of this water table where the problem is severe.

UNDERSTANDING D: Plants are a renewable natural resource.

As mentioned in a previous understanding, the life cycle of plants continues year after year when optimum growing conditions prevail. This feature of plant life places them in the category of renewable resources as opposed to the non-renewable resources. Because of this, plants continue to replenish and increase their own kind. This provides a continuous source of food and shelter for animals, and also provides for an opportunity for plants to revegetate areas where they have been eliminated. Man has learned to take advantage of this renewability in many ways. Non-renewable resources, such as coal and oil, will eventually become depleted; but the renewability of plants gives man a virtually unlimited supply of food and energy provided the environment will continue to support plants.

CONCEPT NO. 2: Many factors affect plant growth, reproduction, and distribution.

Plants are living things that depend on many non-living things for growth and reproduction. Some plants live only a few days while others survive for centuries. During this time, many factors in the environment will influence their life, beginning with the exact requirements for germination of the embryo. As plants grow to maturity, they must obtain everything they need from the habitat in which they are located. Their lack of mobility is one of the basic differences between plants and animals. The seeds of plants can be re-distributed to new locations; but even here, some external force in the environment is required, such as wind, water or an animal.

Environmental conditions may also determine the nutritional quality and quantity of plant life in the habitat. One piece of land may support highly nutritious plants, whereas another area only a short distance away may be devoid of plant life due to soil conditions, topography, climate, or water quality. The abundance of plant life may also be similarly affected by the environment. A desert habitat in Arizona may support a limited number of plants, whereas a tropical rainforest in Brazil may contain thousands of plants in the same amount of space. It is obvious from these two comparisons that the ability of the environment to support life is indicated by the "richness" of the plant life. By richness of plant life we mean the nutritional quality, the quantity of plants in a given area, and the vigor of the growth. Ultimately, the quality of the environment determines the kind of plant life, and the plant life in the area will determine the carrying capacity for animals. This will be discussed at greater length in the chapter on animal life.

UNDERSTANDING A: Geologic conditions and changes create dramatic variations in plant life.

Plant communities have changed dramatically since plants first appeared on earth because of geologic changes. Great forests have become deserts, seas have receded to become areas of lush vegetation, and lush tropical forests have become arctic wastelands devoid of vegetation. Most of these changes have occurred over millions of years, but changes are still occurring today. The eruption of Mount St. Helens and the creation of a new volcanic island in the North Atlantic are examples of abrupt geologic changes that affect plant life.

In Arizona, there is ample evidence of the influence of geologic influences on plant life. A trip from Yuma to Flagstaff will reveal many of these geologic effects. Such things as rocks and soil, topography, and elevation combined with climatic changes create the differences in plant life along the route. Broad valleys with deep soils generally support a large number and variety of plants where sufficient water is available. Black volcanic rocks and lighter colored granite provide parent materials to most of these valley soils in Arizona. The more rocky valley soils and hillsides present special conditions for plant growth, sometimes inhibiting but occasionally increasing the potential for plant life. Run-off of rain from larger rocks may actually increase available water to adjacent soils and plants. Soils that are shaded by large rocks may also provide a micro-habitat for plant growth.

Other geologic formations, such as topography and elevation, influence climatic conditions across broad reaches of the state. The Mogollon Rim, a geologic formation running east and west through the east-central part of Arizona, is a good example of this effect on climate. Warm moist winds from the southwest travel across the desert area from the California Gulf or Pacific Ocean, but may not lose their moisture until they begin to rise against the Mogollon Rim of Central Arizona. As it rises, this humid air cools in the upper atmosphere and falls as moisture in the form of rain or snow producing a lush chaparral in the lower foothills and ponderosa pine forests in the higher elevations. As these dry winds continue to the northeast, they blow across the high plateau country where the lack of moisture has created another desert of sparse grasslands (see accompanying map of the vegetation of Arizona, Figure 5).

Topography can influence plant life in other ways. The north-facing slope of a mountain is generally more shaded and moist than the south-facing slope. The elevation may be the same, but the plant life is significantly different due to longer retention of moisture on the north side. Steepness of the slope will also determine length of time rainwater or snow moisture remains in the soil. If the slope is too steep, erosion of topsoil may also eliminate the necessary seedbed for germination of grasses and other plants. Careful study of any mountain or hillside will reveal differences in plant communities from one slope to another (Figure 6).

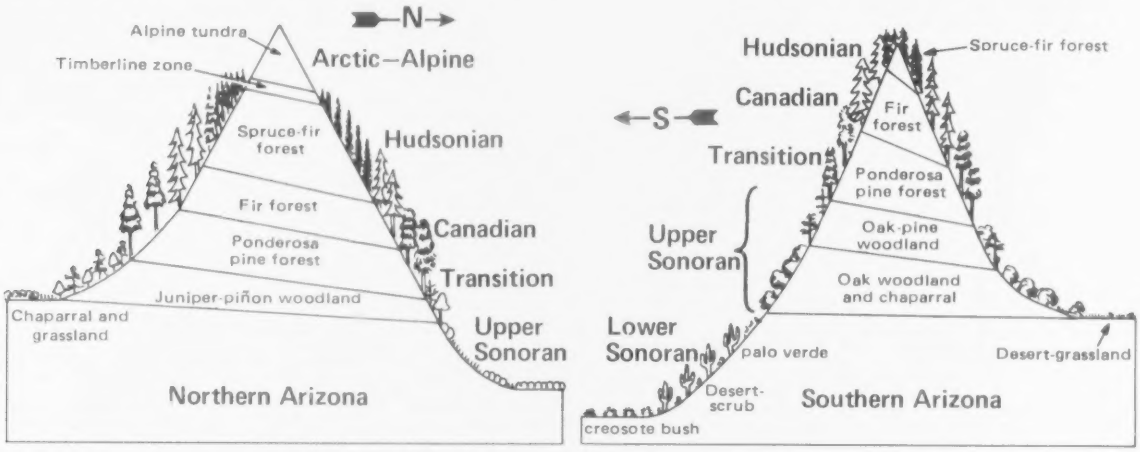


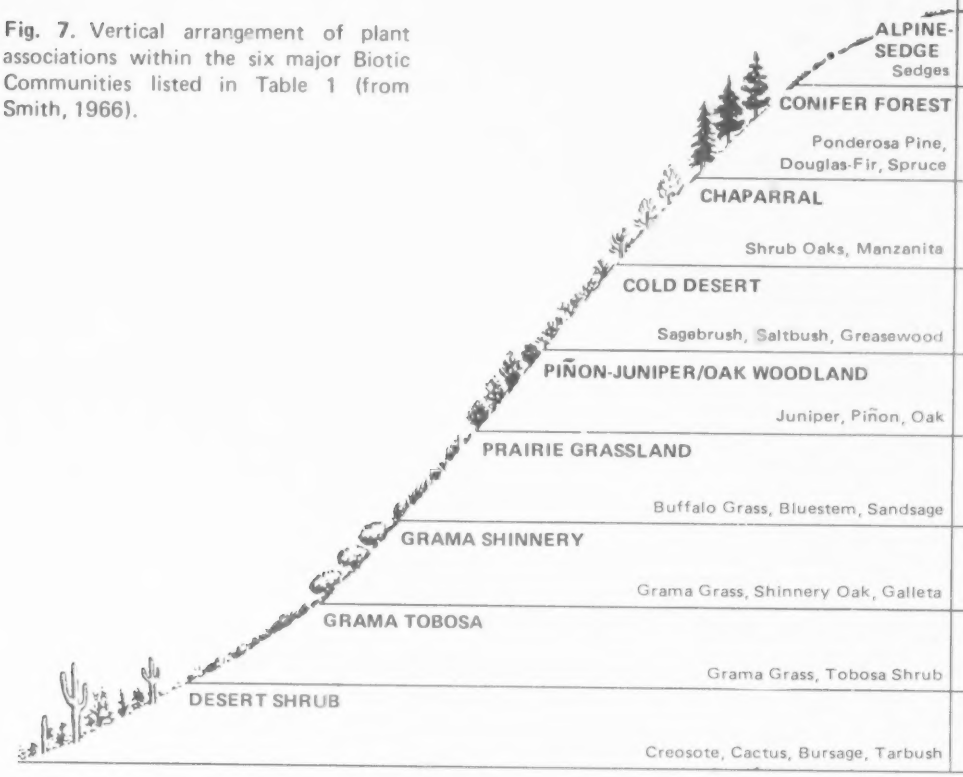
Fig. 6. Biotic Communities of the Southwest showing the plant associations in vertical elevation on north and south slopes of mountains (after Brown and Lowe).

UNDERSTANDING B: Climate and length of day affect growing season.

Climatic changes and weather patterns from month to month and one year to the next will greatly affect plant life in Arizona. The influence of climate on plant life from the north slope to the south slope of a mountain is easy to see. Just as significant is the change in plant life from one year to the next depending on the abundance or lack of rainfall. Length of day can also have a dramatic effect - the long, hot days of summer can scorch the plants in May and June, but create ideal growing conditions when summer rains provide moisture in July and August.

The plant life of Arizona is as varied as the climate. This is not surprising when we consider the importance of sunlight and moisture to plant growth. Vegetatively, the state can be divided into roughly six areas (Table #1 and Figure 7, Vegetation of Arizona). These areas have different climates and different plant life. The low desert areas of the southwest and high desert area of the northeast are the driest parts of the state and, therefore, the most lacking in amounts of vegetation. The northwest and southeast

portions are next in amount of rainfall received and constitute the desert grasslands. The east-central part of the state supports the chaparral, and the cool coniferous forests of the central plateau receives the most precipitation.



	Mean Annual Temp. (F°)	Mean Annual Precip. (Inches)
ALPINE-SEDGE	32	28
CONIFER FOREST	32-45	20-28
CHAPARRAL	45-57	16-24
COLD DESERT	45-50	8-12
PIÑON-JUNIPER/OAK WOODLAND	50-57	12-20
PRAIRIE GRASSLAND	57-70	24-28
GRAMA SHINNERY	50-65	12-16
GRAMA TOBOSA	55-70	8-12
DESERT SHRUB	70	10

Fig. 7. Vertical arrangement of plant associations within the six major Biotic Communities listed in Table 1 (from Smith, 1966).

The pattern of precipitation and temperatures can be as influential on the vegetation as the total amount of rainfall. Roughly half of Arizona receives less than ten inches of precipitation a year, ranging from less than five inches at Yuma to more than 25 inches in the White Mountains. Most of this moisture comes in the form of summer thunderstorms in July and August, and winter rains and snow from November to March. Summer storms originate in the south and southeast, whereas winter rains come from the Pacific Ocean. Winter rains are better for vegetative growth in the deserts, and summer storms usually produce more growth in the higher elevations. Good snow packs that melt slowly can also provide a spring flush of growth in the higher mountains. If rains come too early or too late, they will miss the growing season for many plants. If winters are too cold or summers too hot and dry, some plants, even perennials, may suffer permanent damage or die. Entire hillsides of oak trees and browse plants have been lost to sustained drought. Many desert trees such as mesquite adapt to the arid climate of Arizona by the death of

Table I, Primary Biotic Communities of Arizona

Biotic Community	Elevation (feet)	Annual Precip. (Inches)	Avg. Temp. Jan./July (F)	Typical Location
Alpine Tundra	11,500-12,670	33-80	16 / 48	San Francisco Peaks Coconino County
Coniferous Forest				
Spruce-alpine fir	8,500-11,500	30-35	21 / 53	Kaibab Plateau & Higher Mountains
Douglas fir	7,500-9,500	25-30	25 / 58	Higher Plateaus Above pine assoc.
Ponderosa pine	6,000-9,000	18-26	24 / 65	Northern Plateaus Southern Mountains
Evergreen Woodland			34 / 74	
Juniper-pinyon pine	5,500-7,000	12-20		Northern Arizona
Oak-pine woodland	4,000-6,500			Southern Arizona
Chaparral				
Interior Chaparral	4,000-6,000	13-23		Central Arizona
Grassland			41 / 83	
Mountain grassland	6,000-10,000	25-40		Coniferous forests
Plains grassland	5,000-7,500	11-18		Eastern half of Arizona
Desert grassland	3,500-5,000	10-15		Southeastern Arizona
Desert scrub			47 / 93	
Great Basin (cool)	3,000-6,500	7-12		Northwestern Arizona to Flagstaff
Southwestern (warm)	100-4,000	0-10		Southwestern Arizona to Tucson

one or several limbs - a natural "pruning". This explains why many living desert trees have dead limbs - a natural condition.

Other climatic factors which can cause severe damage to plants are high winds, lightning, and long periods of freezing temperatures. Saguaros that have survived for centuries may topple in a high wind, especially when the soil has been saturated with moisture. Prolonged freezing temperatures can also damage cacti and other succulent plants. Lightning usually takes its greatest toll in the coniferous forests of Arizona just prior to summer storms when tall pines and firs are exceptionally dry. Forest fires are also more prevalent at this time of year. Some of these fires can be beneficial if they do not burn too hot; but many summer fires that are the result of lightning strikes or careless campers can be extremely detrimental to plants, especially if they occur in heavy brush or timber.

UNDERSTANDING C: Plants are interdependent with other plants and animals.

An ecosystem is composed of many plants and animals which are interdependent in a natural environment. This ecosystem is a self-sustaining unit which is dependent only upon the sun for energy. Plants must therefore compete with each other for energy from the sun, for water and nutrients from the soil, and for space to survive. In Arizona, the most critical limiting factor to plant survival is the availability of water. Mesquite trees, for example, are very successful in this regard. They do not readily tolerate competition from their own species or other plants in arid sites. In places where underground water is more abundant, such as desert washes and river flood plains, mesquite trees may form bosques (boss-keys, Spanish for forest). But even in these dense thickets, mesquite are very competitive with other perennial plants for survival, and only a few hardy shrubs will survive.

There are times when plants need other plants to provide a proper micro-habitat for survival. The seedling saguaro needs a "nurse tree," such as a palo verde or mesquite, to provide protection during its early growth. Young fir trees need the shade of taller trees to grow well, but too many fir trees or pines can also result in stunted growth due to competition for space and moisture. Natural thinning from disease or fire will eliminate weaker trees and permit stronger ones to grow to maturity. This is an example of "natural selection." Man can duplicate this effort by artificial thinning. Other plants, especially grasses and shrubs, can benefit from thinning the overstory and allowing more sunlight to reach the ground. These plants will in turn benefit ground dwelling animals and create a more diverse ecosystem.

UNDERSTANDING D: Diversity of plant life influences the diversity of animal life.

Diversity, or variety, in the ecosystem usually creates a healthier, more stable habitat. If one species of plant should die, another similar species is available to fill the niche. A diversity of plant life portends an equally diverse animal life. No one species of plant or animal becomes dominant to the exclusion of all others. "Variety is the spice of life"; it is also the strength of an ecosystem.

Most native plants and animals have existed together for centuries in what is often called a balanced ecosystem. The proper number of large herbivores can actually benefit plant life. Under moderate utilization, grasses and shrubs will usually increase in vigor and increase production of forage and seeds. For example, a lawn or hedge can flourish when both are frequently trimmed the correct amount. "Take half and leave half" is a standard rule of thumb in good forage management involving management of livestock or wildlife.

A classic example of the reverse effects of wildlife on plant life was exhibited on the Kaibab Plateau north of the Grand Canyon in the late 1920s. All predators were considered "bad" at the turn of the century, so an intensive effort was made to remove all of the lions, coyotes and wolves from the Kaibab. The famous mule deer herd increased in a few years to nearly 100,000 animals, and by 1927 a natural die-off carried the numbers back down to less than 10,000 animals. Most of the desirable plant life had been eaten by livestock and mule deer, and the remaining deer had little forage left. Today, after more than 50 years, the forage plants have not recovered their former growth; but less desirable forage plants (invader plants) such as juniper, have filled the void left by the dying plants. Today, the carrying capacity of the Kaibab forest is less than 20,000 deer.

Hopefully, man has learned a valuable lesson from the Kaibab: we cannot "stockpile" deer herds or any other large herbivore without disastrous effects to plant life. Under proper management, cattle, deer, sheep and elk can actually benefit plant life; but a range or habitat can be destroyed in only a few years and may take many years (if ever) to recover. The removal of grass cover by overgrazing may allow topsoil to erode and wash away; topsoil that may have taken centuries to build.

CONCEPT NO. 3: Plant communities form important parts of the earth's environment.

Plants existed on earth long before the first animals arrived. Primitive plant communities formed the basic habitat for the development of animal life. As geologic and climatic conditions permitted, plants began to develop slowly through geologic succession as

aquatic plants, and finally as terrestrial species. Through genetic changes, plants gradually adapted to new and different environments until today, more than 350,000 species have been identified. Members of the plant kingdom are found on every continent and in every major body of water in the world.

Because plants growing in a natural habitat are usually interdependent with other plants, they are normally referred to as plant communities. These communities change from one place to another, from one season to another, and sometimes after cataclismic or other natural events have disrupted their growing conditions. These communities support animals living in the area and are therefore the basis for biotic communities.

UNDERSTANDING A: Plant species are unique and identifiable.

Just as we are given names in order to separate one person from another, we give plants names in order to talk about them. Plants are therefore separated into groups by their particular growth characteristics. We begin with very broad groups which are easily identified. Each broad group, such as seed producers and spore producers, can be divided again and again until individual species are identified.

The final growth forms or "key characteristics" include such things as leaf and flower arrangement, size, and shape. Perhaps the easiest classification of Arizona's terrestrial-plants is by growth form: algae, fungi, mosses, grasses, grass-like plants, forbs (weeds and flowers), shrubs, trees, cacti, and succulents. Another large group of plants includes the aquatic plants which, as the name implies, live in water. These are not as easily observed and are generally classified as floating, submerged, and emergent, depending on their location and growth form in the water.

UNDERSTANDING B: Plant communities consist of different combinations of plant species and are the foundation of biotic communities.

The smallest micro-plant community may be a lichen bed on a rock or patch of moss in the shade of the same rock. In both examples, the micro-climate of temperature and moisture provides a habitat which is different from the surrounding area. A classroom terrarium or patch of grass in the crack of the sidewalk are examples of man-made micro-habitats. A forest or grassland of many square miles represents a macro-habitat plant community which may contain many smaller plant communities.

The natural vegetation of Arizona is divided into six major biotic communities (Table I) which can be identified by the dominant kind of plant life. These are further divided into plant associations within the larger communities (Figure 5). In addition to these, riparian communities are found along rivers, streams and washes through these larger communities at almost every elevation from the lowest deserts to the coniferous forests. These riparian areas are composed of deciduous trees and other water-loving plants which differ considerably from those plants in the drier surroundings. Meadows and cienagas are also found at practically every elevation and consist of grasses, sedges and rushes which are better adapted to moist areas.

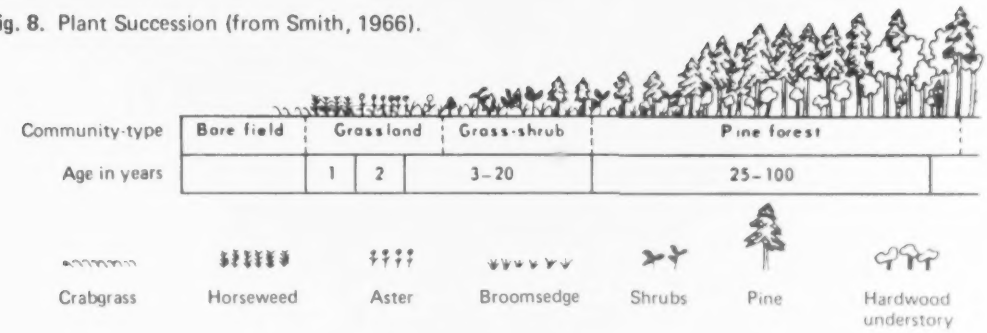
Other sub-communities include mesquite forests (bosques), salt brush flats, creosote bush association, cacti-palo verde-sage associations, yucca grasslands, and, in the highest elevations, groves of aspen trees. The natural vegetation of Arizona includes practically all of the plant communities of North America between the tropical forests of Southern Mexico to the Arctic tundra of Northern Canada (Figure 5, Vegetation of Arizona).

Plants provide most of the habitat requirements for the survival of animals either directly or indirectly: food, shelter or cover, and sometimes the entire water supply in desert habitats. Some animals, such as the cactus wren or savanna sparrow, are restricted to one plant community or even sub-community. Aberts' squirrels are associated primarily with ponderosa pine forests. Other animals are extremely adaptive. Mule deer are found as subspecies in the southwestern deserts and throughout the entire Rocky Mountain area; and coyotes have expanded their range to include the entire U.S., including the suburbs of many cities. In general, the plant community will determine the kinds of animals to be found in an area and are therefore the basis for biotic communities, which includes both plants and animals (further discussions will follow in the chapter on animal life).

UNDERSTANDING C: Plant communities are constantly changing.

Before plants appeared, the earth was barren of life, but consisted of the basis for plant growth - water, rocks, soil, and atmosphere. Gradually, as the environment permitted, the first plants began to appear. Lichens grew on solid rock where a scant amount of moisture would support the growth of fungi and algae. As rocks eroded and became soil, more plants such as mosses appeared providing the environment included sufficient moisture. This was the beginning of the slow process of geologic plant succession (Figure 8) which must precede the development of a pine forest or a grassland or desert.

Fig. 8. Plant Succession (from Smith, 1966).



This succession often requires many centuries to complete, especially when mature forests are the climax vegetation.

Another kind of succession occurs after a forest fire; bare soil to weeds and annual grasses, to perennial grasses and shrubs, and again if the environmental conditions permit, a forest. As indicated in Table I, Biotic Communities of Arizona, the type of plant community in a given location depends a great deal on the climatic factors of temperature and annual precipitation. When the plant life in a community remains the same for many years, barring a fire, flood or other ecological disturbance, that community is said to have attained climax (see Figure 9, Plant Succession).

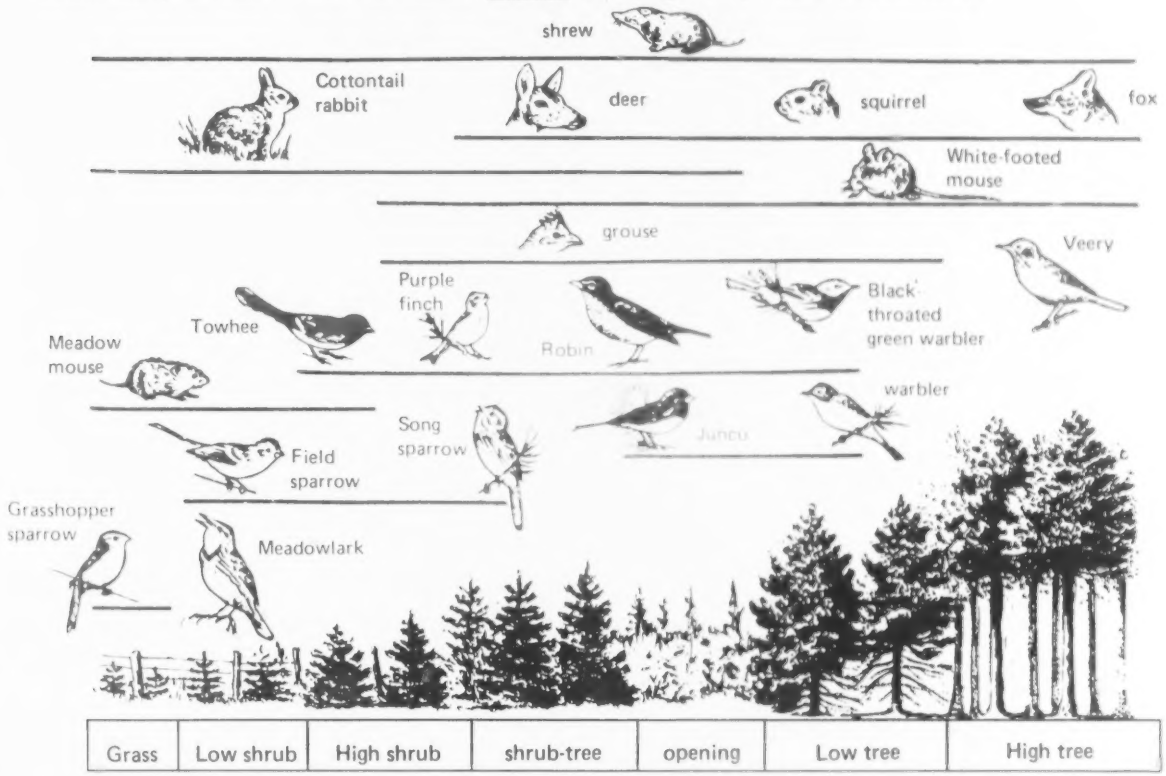


Fig. 9 Succession of plant life followed by a succession of animals to end in an ecologic climax biotic community (from Smith, 1966)

If a vacant lot in the city is scraped clean to bare soil, it will eventually undergo a succession and eventually reach a climax vegetation provided the seed source is available, and environmental conditions are similar to that which had existed before the land was cleared, and seeds can germinate. The vacant lot in Gila Bend may return to a creosote bush desert; in Flagstaff, the vacant lot will eventually grow pines. These two examples of succession may take place at a slower rate in Gila Bend than in Flagstaff due to differences in environmental conditions.

UNDERSTANDING D: The diversity of plant life influences animal diversity.

As mentioned in previous understandings, plant succession after a disruptive event such as a forest fire is usually followed by a succession of animal life (Figures 8 and 9). The bare soil created by a forest fire will not support animals until a few weeds and grasses sprout and grow. As the vegetation appears in an area, the animals gradually invade the area. First to arrive are the seed eating birds and insects, then the insectivorous birds and, perhaps, a few insectivorous lizards and snakes from surrounding areas. Seed eating birds may also introduce new plants to the area. As the plants become established and perennial grasses and shrubs develop in the area, the ground nesting birds move in to inhabit the area. Gradually, the larger animals move into the area - the rodents and rabbits and the animals that feed on them: the snakes, hawks, owls, foxes, and coyotes. Gradually, as the plant life increases to include shrubs and small trees, the tree nesting birds and larger mammals begin to invade the area to browse on the grass and shrubs.

A good mixture of forbs, grasses, shrubs and trees will eventually support many different species of wildlife. If plant succession continues to the climax vegetation of the original pine forest, many of the grasses and shrubs are again lost. This is due to the loss of sunlight to warm the soil and lack of moisture due to competition from large trees. Animals will also be restricted to the tree dwellers, tree squirrels, jays, creepers, woodpeckers and other birds dependent entirely on mature trees.

Thus, it is quite clear that the kinds of plants in an area will influence the kinds of animals found there. Similarly, the abundance of plant life will also determine the carrying capacity of the area to support a given number of animals. One acre of irrigated land may support one cow and calf, whereas it may require 60 to 70 acres of native grassland to support the same cow. This will be discussed at greater length in the chapter on animal life.

UNDERSTANDING E: Man has created many changes in plant communities

Through manipulation of the environment, man has caused tremendous changes in the aquatic and terrestrial plant life. When man learned to cultivate and domesticate plants, he eventually converted thousands of acres of bottomland to crops to feed himself and his domesticated animals. As the bottomland became scarce, hillsides were terraced and more marginal lands became available to agriculture. Original plant communities were reduced or eliminated to make way for more productive crops that could be harvested for food.

Man has also inadvertently affected natural plants, often to the detriment of the biotic communities. Overgrazed grasslands at the turn of the century in Arizona created erosion and resulting loss of valuable topsoil. Shrubs and annual forbs invaded to create an entirely different community. Animals that preferred grasslands, such as masked bobwhite and antelope, were eliminated and replaced by species that preferred a shrub and tree community, such as Gambel's quail and mule deer. Other ways man has adversely effected plant communities is through wild fire and air pollution. These activities of man will be discussed at greater length in the chapter on Man In The Environment.

CONCEPT NO. 4: Plants provide many essential materials for modern civilizations.

UNDERSTANDING A: Plants provide many of man's basic needs.

We have only to consider some of the things we see and use daily to begin to understand and appreciate the importance of plants in our lives. Food, paper and wood are ever present products made from plants. There are less obvious yet equally important ways that we utilize and depend on plants.

Plant fibers, such as cotton, hemp and jute, are important in producing textiles, fine fabrics, home linens, etc. Arizona accounts for 10% of the United State's production of cotton.

Uses of substances extracted from plant cells provide an enormous variety of useful items. These include medicines, flavorings, perfumes, dyes, insecticides, beverages, oils, fats, paints, resins, etc. There are over 20 different kinds of acids, several types of alcohol, 22 different enzymes, antibiotics and vitamins derived from molds alone.

Medical history was made in England in 1928 when Sir Alexander Fleming discovered the usefulness of Penicillium mold in treating diseases caused by bacteria. The final chapter in the story of antibiotics remains to be written for present research is seeking even more useful and specialized drugs from various molds from all parts of the world.

Food plants, above all others, are essential for the very existence of man. Without agriculture, man would have remained a hunter-gatherer, unable to direct his intellectual capabilities to areas other than where and when he would eat next.

UNDERSTANDING B: Ancient plants converted to coal provide a useful source of stored energy.

Coal is an energy resource derived from huge tropical forests trapped in sediments of ages past. Historically, man used wood and then coal as sources of energy. Because of its abundance, coal was the primary source of energy for a growing industrial society in Europe and North America. Eventually, because of relative ease in extracting and transporting, oil and natural gas became the primary energy sources for the 20th Century. Ironically, we are now seeing a shift back to the use of coal as a reliable supply of petroleum becomes increasingly difficult to obtain in a energy dependent world.

Coal deposits of today actually represent the storage of solar energy in the form of fossil plants which were living many millions of years ago. Coal, oil and gas deposits are limited natural resources and are rapidly being utilized by today's industrial societies. As these reserves of stored energy are used up, man may find it necessary to convert his energy needs to that of solar energy which is the original source of all energy and is virtually limitless.

UNDERSTANDING C: Man's increased use of plants and their by-products will require more intensive management of earth's plant life.

As the need for food and substitutes for non-renewable products increases, the demands upon plant resources will increase.

The "Green Revolution" had its beginning in the late 1960s with the development of specific strains of wheat that would produce 100 or more bushels per acre. Other crop strains are being developed that will increase the harvest without increasing the amount of cultivated land.

Crops of increased productivity are a tremendous breakthrough in fighting world hunger. Vast areas of single crops have been planted. This method of monoculture can be maintained only with increased use of weed and pest control. New and stronger pesticides have been continually developed as vast areas of single crop types provide an environment suited to rapid reproduction and adaptation of insect pests to existing pesticides.

Maintaining a monoculture raises many questions about the constant use and dependence on pesticides. Some pesticides have been banned because they are highly toxic and persistent in the environment, and thus represent a danger to other living things. There is also the possibility that new pesticides will not be developed in time to keep up with constantly adapting insects, and entire crops may be lost. Because of these problems, a new technique of pest management has evolved - Integrated Pest Management or IPM. This technique involves the use of all of the known methods of controlling weeds and pests before the use of chemicals becomes necessary. Such cultural methods as crop rotation, plowing under older plant stubble, timing of planting and harvest, and biological control by use of predators, repellents, attractants, and other physical, chemical and biological substances are becoming more popular and practical than pesticides (also see allemones and pheromones in the glossary).

Some products such as plastic that are presently produced from non-renewable resources (i.e., oil and coal) can also be made from plant cellulose (wood). There are also plant substitutes for products derived from other limited resources. The jojoba plant commonly found in Arizona deserts produces a bean from which oil is extracted that has the same properties as the oil derived from the sperm whale.

But there are limits to the number of plants, crops, and forests that can be grown in a particular region, limits that are determined by factors that have been discussed in previous understandings. Attempts to increase or exceed the productive capacity of an area may succeed in the short run, but long-term effects may decrease the total yield. The end result may eventually be an area with a capacity less than the original. It is evident that man's ability to manipulate plant life to produce necessities is limited by other resources with which he has to work - space, soil, water, climate, air, and many as yet undiscovered factors in the environment. Artificial environnments such as greenhouses have not been developed to the extent required to produce large quantities of food which are needed to support an ever expanding human population. It will therefore become imperative to utilize more efficiently our rangelands, forests, croplands, and, eventually, our lakes and seas.

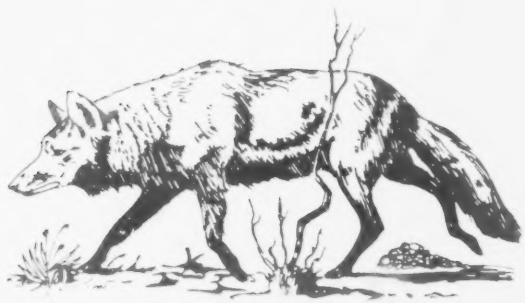
ANIMALS

BACKGROUND

When we talk of animals, we don't just mean deer and mountain lions. We must also consider our pets and, even, ourselves. Wildlife, such as deer and mountain lions, as well as ants, Gila monsters, tarantulas, and hundreds of other species of wildlife all fit into the diverse category we call animal. Another important group of animals in Arizona includes domestic cows, sheep, and goats that range our deserts and mountains, as well as the dairy cows, chickens, pigs, and other animals raised for meat or other products.

All animals require the same basic components to survive: a place to live, food to eat and water to drink, shelter or cover, and the proper arrangement of these components. These components make up habitat. Even though animal needs vary from species to species, all animals require the components of habitat in some form.

The kind, quality, and quantity of available habitat also determines the kinds and numbers of animals found in an area. Animals, as with plants, are a product of their habitat. Because of this, specific animals are adapted to specific environments. The polar bear would fare no better in the desert than would the cactus wren in the Arctic.



Any area of land, water, and ultimately our planet, has a finite amount of resources available. The numbers of plants and animals that an area can support is called the "carrying capacity". A given area can only support so many termites, buffalo, or cactus wrens, just as an area of farmland can only support the growth of a finite quantity of a crop.

Animals are affected by changes in their habitat. For this reason, they may be used as a barometer of environmental quality. Monitoring of sensitive animal species may give us insight into impacts on, and the condition of, the environment. Animal species are interdependent on each other and interrelated. This interrelatedness is expressed in the exchange of energy and matter, with each other, and the environment. This exchange occurs through food chains and food webs.

Animal populations are in a dynamic ecological balance with their environment. Animals are a renewable resource that can be managed and conserved. Some animals, such as problem insects, must be managed to control and lessen the negative effects on agricultural or forest resources. Management practices must stay within, and attempt to maintain, the ecological balance.

Animals have many values to humankind. These include economically important consumptive values such as meat and meat production, trapping of wild animals for fur, and hunting. Animal resources directly and indirectly provide jobs for people such as veterinarians, ranchers, or dairy farmers. Animals also have nonconsumptive values that can be economically important. These include bird watching, photography, and the care and enjoyment of pets. Spiritual, cultural, and aesthetic values of animals cannot be easily quantified but are evident in our literature, religion, and art.

The subject of animals is a diverse and fascinating one. It includes all of us and our relationships to what is around us. Animals are an integral part of our world.

CONCEPT NO. 1: Animals are dependent upon their habitat for existence.

All animal life, from ants to elephants, have the same basic survival needs. Unique combinations of sunlight, things geologic, water, and climate (the resources discussed in earlier chapters of this guide) produce habitats that are inhabited by those species best able to survive there. Each environment produces a particular community of plants which, in turn, supports certain combinations of animals. For example, the polar bear is well adapted for life in the frigid arctic environment. Yet, if this animal were suddenly placed in a desert environment, it would probably die. Animals are a product of the land they live in and the existing condition of that land.

UNDERSTANDING A: The environmental components of an area determine what life forms will occupy that area.

The physical and climatic features of a given area - its elevation, rainfall, topography, plant communities, soil types, successional stage, distance from the equator, historic activity of fire, man's use or abuse, geological events, and many other components help to determine the species and numbers of animal life in a given community. A comprehensive description of a particular environment, here in Arizona or in any part of the world, will usually predict the specific types of resident wildlife that exist there. The grizzly bear, a former resident of Arizona, can be compared to the European brown bear, which lives in a very comparable habitat. In each case, the comparable ecological niche is filled by a similar animal.

UNDERSTANDING B: The five essentials of animal habitat necessary to all species are: food, water, shelter, space or territory, and the arrangement of these elements in relationship to each other.

As previously pointed out, all animals, including humans, depend upon their habitat. Habitat is not a homogeneous thing, but rather a number of integrated components, including food, water, shelter or cover, space, and the proper arrangement of these components in relation to each other.

It is easy to understand that animal life needs food, water, and shelter, but when we begin to define these simple words in relation to various species, it becomes very complex and fascinating. For example, cover or shelter means not only cover to hide in, but cover to travel in, cover as shelter from the elements, cover for stalking, cover for breeding, and cover for bedding, etc. Even when we consider only one specific type of cover it varies greatly between species. For instance, the nesting cover of an acorn woodpecker differs greatly from that of a great blue heron. Understanding the various food needs requires a careful consideration of the animals' needs by season, good or bad food years, competitors, and many other aspects.

Water needs of animal life can vary from those of the kangaroo rat, which uses no free water, to the needs of a fish which must live in water, travel in water, and find shelter in water. Domestic animals like cattle, that are introduced into an area such as a desert range, often require additional water sources such as a manmade stock pond. If additional water sources are not supplied, animal production may lessen, or the cattle may negatively impact native wildlife through competition for water. Stock ponds may also be beneficial to the native wildlife, especially in dry years when the rancher is hauling water to an otherwise dry range.

Another important requirement is adequate space or territory. This aspect, as with the others, varies tremendously from species to species. A cactus wren may defend a territory of only a few hundred square feet, whereas a mountain lion may use a home range of 150 square miles. The "home range" or "territory" of an animal is the space that it requires in order to meet its needs and survive. Size of the area used may depend on habitat quality, social interactions, breeding behavior, or other factors. Territories differ from home ranges in that a territory is actively defended, whereas home ranges generally are not. A rooster in a barnyard may establish a territory and rigorously defend it from other roosters. Animals, such as the mountain lion, that establish home ranges, will

usually just avoid each other in areas of overlapping home ranges rather than actively fighting. Areas of two species may overlap, but as long as the two are not in direct competition, they will coexist. A cardinal might vigorously evict another cardinal from his territory, but will ignore a mockingbird in the same area. Space is an important understanding when considering the needs of animal life.

The food, water, and shelter components of an animal's habitat must be properly arranged for that species to be able to make use of it. When food is too far from bedding shelter and water is too far from escape cover, that habitat may not be suitable for a particular animal species. Each species has its own measurements of these distances. A waterhole that might be too far for a porcupine or a tree squirrel to use may not be too far for a cow or an elk.

UNDERSTANDING C: Every habitat has a limited carrying capacity.

At any given time, there is a finite amount of resources available to animals on a given area of land. The numbers of animals that the land will support and sustain is called the "carrying capacity". Every unit of land or water, and ultimately, the planet, has a carrying capacity for plants and animals. This carrying capacity is controlled by climatic, geological, biological and/or social factors.

Every animal habitat has a finite capacity to produce, just as a particular piece of farmland has its own fenced boundaries and specific production capability. An animal habitat can produce only so many horseflies, fence lizards, meadowlarks, cows, catfish, or buffalo. The carrying capacity of an area may be determined by a resource that is in short supply or in excess of the tolerances of an animal. This is termed a "limiting factor". For example, if a lake is so muddied by erosion from the surrounding watersheds that sunlight can no longer penetrate the water, the microscopic plants (primary producers) which live in the lake may not be able to carry on photosynthesis. Without this energy production, the food chain of the aquatic plant-insect-minnow-large fish is broken. The limiting factor of the large fish population then becomes the food supply, in this case, the lack of minnows. But indirectly, the lack of photosynthesis due to soil erosion is the primary limiting factor for the entire food chain.

The carrying capacity of any habitat may vary from season to season or year to year. As these changes in the carrying capacity occur they will also have an affect on the numbers and well being of the resident animal populations. If a particular habitat is undergoing a

drought and, consequently, a reduced production of plant life, the mule deer or cattle which inhabit that area may have less young survive in that year because of the lack of vegetation for food and cover.

Migratory herds of mule deer, such as those on the North Kaibab may not reach carrying capacity on their summer range while exceeding the carrying capacity of the winter range which is poorer quality habitat.

UNDERSTANDING D: Animal species and their numbers are affected by changes in the quality and quantity of their habitat.

Animal population levels are determined by the quality and quantity of the habitat. Some habitats have a higher "carrying capacity" due to higher quality and can support a higher density of animals. Black bears in the Central Arizona chaparral have much smaller home ranges, and therefore, a higher density than black bears in the ponderosa pine-mixed conifer vegetation type. Habitat quality is better in the chaparral, therefore, the bear does not need as large an area to meet its needs. The chaparral has a higher carrying capacity for black bears than does the ponderosa pine-mixed conifer.

The extent of the habitat determines the distribution and total numbers of animals. For example: there are more acres of pronghorn habitat in Wyoming than in Arizona and, consequently, a larger total population of pronghorns. However, the density of pronghorns per a given square mile might be as high or even higher in Arizona. In Florida, an area of grazing land can support more cows per acre than an equal area in the deserts of southern Arizona. All of this relates directly back to the ability of the habitat to supply the needs of a particular animal species.

Most animal species differ in their ability to adapt to change in their habitat. The more specialized an organism becomes, the less adaptable it is and less able to survive environmental change.

Those species which are very specific in food needs or other habitat needs can easily be decimated by the loss of or damage to that need.

Fish-eating birds, such as the bald eagle, are an excellent example. When the water is polluted, fish die and the fish-eating birds may be forced to migrate or eventually die. If the area is at carrying capacity for eagles, the birds have nowhere to migrate to and will

be lost from the population. If the fish have too much pesticide deposited in their fatty tissues, eggshells of the birds that eat the fish may be so thin they will not hatch. Either way, the population will be reduced. Coyotes, on the other hand, are opportunists. They can and will eat carrion, rodents, deer, insects, and plant materials, depending upon the availability. They also have the ability, if all else fails, to raid your garbage can or eat your pet cat. Because of their ability to exploit most changes in their habitat, the coyotes are not so vulnerable to depletion.

CONCEPT NO. 2: Animal species are interdependent with one another and with their environments.

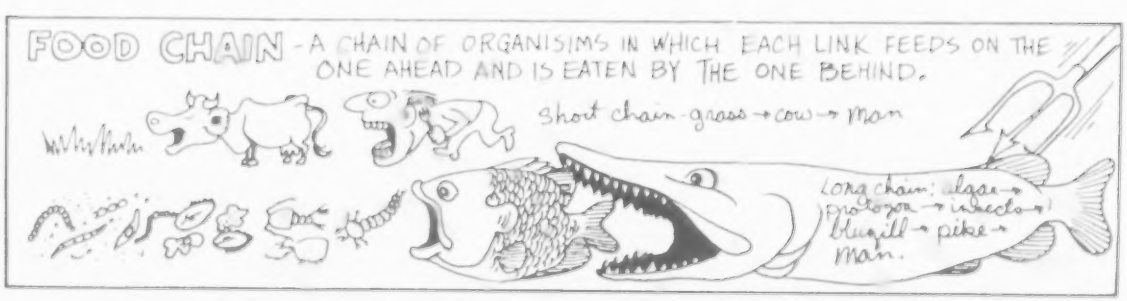
All plants and animals in an ecological system live in an intricate web of interdependence and interrelatedness.

The food webs and energy chains in a particular environment best illustrate the interrelatedness of all living things. In a normally functioning ecosystem, species and environmental factors interact to keep animal populations in dynamic balance with each other and with their habitat.

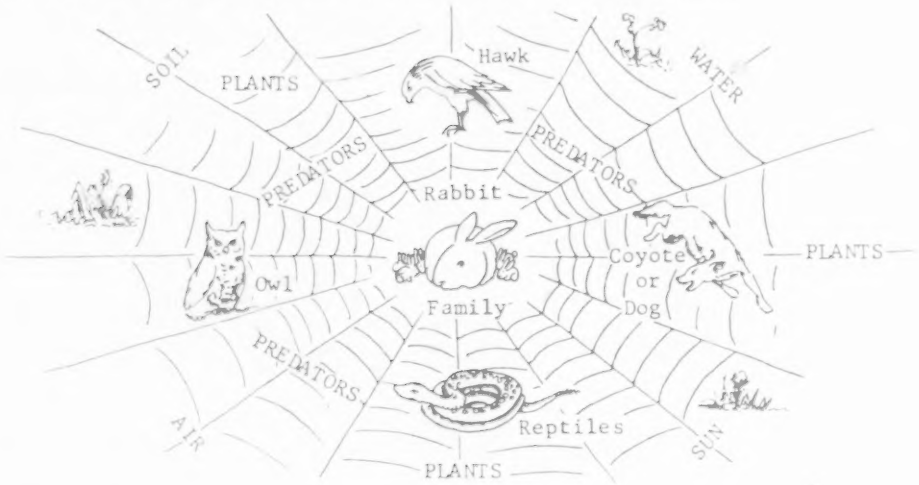
UNDERSTANDING A: Living things exchange energy and matter with the environment and with each other.

The essence of life begins with light from the sun, and is continued by the transference of this energy from sun to plant to animal. Every ecosystem can be divided into levels of life, starting with the producers, i.e., the green plants and moving up into the herbivores and, ultimately, the carnivores, the top of the food chains. At each level of life, there is a transference and loss of energy of approximately a factor of ten.

This linking of energy from organism to organism is called a "food chain". Each organism has its own very specific food chain.


FOOD CHAIN - A CHAIN OF ORGANISIMS IN WHICH EACH LINK FEEDS ON THE ONE AHEAD AND IS EATEN BY THE ONE BEHIND.
Short chain - grass → cow → man
Long chain: algae → protozoa → insects → bluegill → pike → man.

Often the food chains of some animals overlap that of other animals. The interlocking pattern of these food chains is sometimes called "the food web" or, the "web of life". Through this fantastically complex web flows energy and matter circulating from organism to organism and from organism back to the environment.



UNDERSTANDING B: Living things are interrelated through "food chains" and "food webs".

We have learned that each living thing depends upon, and is part of, a food chain. Further, we know that these food chains overlap and interconnect. The cottontail is eaten not only by the coyote, but by the owl, snake, bobcat, hawk, and man. The flying insect may be part of a food chain for a toad or a skunk, a snake or a raccoon, a trout or a sparrow hawk. Grass may be eaten by rodents, birds, cows, goats, sheep, or buffalo.

UNDERSTANDING C: Animals are a part of the diversity and balance of the ecological system.

Animal life plays an important role in the environment that it lives in. Animal species and environmental factors interact to keep populations of both plants and animals in balance with their environment. Some animal species compete with others for food, space, water, or other needs. Some species are neutral in their effects upon each other or the environment. Others are mutually beneficial, or may be of benefit to one, and harm to another. The whitetailed deer and the wild turkey may compete for autumn acorns, and a badger may dig for the same rodents that the bobcat stalks by moonlight. A zebra-tailed lizard and a Gila monster may have a completely neutral relationship.

The prairie dog is the primary prey of the blackfooted ferret. However, if we remove the ferret from the ecosystem, the prairie dog often overpopulates its habitat to the extent that it increases the chances of a rampant disease decimating its population. While the relationship of predator and prey is obviously not beneficial to the prairie dog that gets eaten, it is an important one in the ecological system. In the prairie environment, the large grazing animals may provide a beneficial relationship to the grass by grazing it and stimulating new growth. However, if this grazing goes beyond the tolerance of the plant, the relationship can be a negative one in that the plant may be suppressed or even die, thus lowering the amount of food available for the grazing animal.

UNDERSTANDING D: Animals can be a barometer of environmental quality.

All living things respond in a positive or negative way to changes in their environment. When an environment shows enhanced quality (with reference to a single living thing), the organism responds by increasing growth, life span, health, or most commonly, by increased reproduction. In a deteriorating environment, that same organism may show stress, starvation, and reduced reproduction.

Because of its dependence upon the environment, all animal life can be used as a barometer or indicator, of the quality of that particular environment. On a good browse range, a mature mule deer doe will normally produce two fawns. These fawns will have a good chance of survival because of the quality of the range. On a poor or overgrazed range, this same doe may give birth to a single fawn whose chances of reaching maturity are much slimmer. Cows usually react in similar ways to existing range conditions.

In the early 1960's, scientists noticed a dramatic decline in bald eagle numbers. After intensive research, it was determined that the eggshells of the bald eagle were significantly thinner and were not hatching properly. After further research tests were conducted, it was found that the pesticide DDT was the cause of the eggshell thinning. The bald eagle was responding to the pesticide in its environment that was being passed upward through the food chain. Monitoring sensitive animal populations can give us an indication of the relative health of the supporting environment and thus provide an early warning system that something may be amiss.

GOOD HABITAT
PRODUCES A
WILDLIFE ABUNDANCE . . .

WE CAN REBUILD
WILDLIFE HABITAT!

CONCEPT NO. 3: Animal populations and their environments are not static, but are in constant change.

UNDERSTANDING A: Changes in the environment affect living things.

The environment is dynamic - a pulsing complex of living and non-living elements, each part related to, and affected by, other parts. Parts of the environment change daily, some seasonally, and some over long periods. Plants, directly or indirectly, are the source of food for all animal life. Plant populations change seasonally and are dramatically influenced by rainfall, temperature, and other factors. Acorns are available to wildlife only during the fall; fruits and berries, in the summer. The fresh greenery, so high in vitamin A, comes with spring and is welcomed not only by the wild creatures, but domestic livestock as well.

These are highly visible changes. Many changes are subtle and difficult to discern. Some change is local and small in impact, but the collision of continents, or the beginning or end of an ice age, are colossal interruptions of systems eons old. Mount St. Helens' 1980 eruption was miniscule in comparison.

As mountain ranges are uplifted, usually over long periods of time, climates change. With climatic change, plant life changes, and animal life must adapt or perish. If a plant requires ten inches of annual rainfall, it must adapt or become extinct when rainfall patterns change and produce only five inches. . . or fifty-five. Butterflies who lay their eggs only on specific plants, or herbivorous mice which depend largely on the seeds of certain plants, are then in jeopardy and must adapt or face extinction when these plants disappear.

Interruptions of environmental systems, by man or nature, can be instantaneous and allow no time for individual adaptation. However, over time, species may make dramatic adaptations.

UNDERSTANDING B: Succession is the gradual and continuous replacement of one kind of plant or animal by another.

The edge of a vegetative community is ever changing. Where forest meets meadow, the forest advances into the meadow when conditions favor trees and retreats when conditions favor the grasses and forbs of the meadow. If the conditions continue to favor trees, the meadow will become forest. A lake begins to fill. . . becomes a swamp, a meadow, and finally, a forest, as one vegetative type succeeds another.

As the plants change, the animal life changes. Animal succession follows the patterns of plant succession; the grebe or merganser which eats the fish in the lake is replaced at the top of the food chain by water snakes, which eat the frogs, which eat the more abundant insect life of the swamp.

As the swamp is slowly filled in by decaying plant and animal materials and by soil from surrounding areas, it becomes a wet meadow. This, in turn, becomes a dry meadow - with shrews and foxes and owls eating the mice and gophers who utilize grass seeds and forbs. Cabbage butterflies are seen instead of dragonflies, bees pollinate the clover.

When the forest replaces the meadow, the woodpecker finds pinebark beetles to hammer for. The goshawk hunts the forest depths searching for squirrels, and the abert squirrel searches for truffles at the drip-line of the ponderosa pine tree. A bear or a racoon might den in a hollow tree. . . wild turkeys promenade the forest aisles.

A fire might return the forest to a meadow, and the process of succession would recommence.

UNDERSTANDING C: Given sufficient resources, a population will continue to increase until some limiting factor is imposed.

As environmental conditions change, animal life from surrounding areas colonizes newly acceptable habitat. Warblers from the surrounding forest find new territories and nesting sites. Their populations increase to fill the vacant niches. Salamanders appear in the murky waters of the swamp; the prolific cottontail soon fully occupies the meadow. Those that prey on warblers, salamanders, and cottontails quickly follow.

But there are limits within which each species population must function. . . limits dictated by food supply, by predation, by available water in a desert area. The cottontail populations may increase hugely, for a time, but, when a limit is reached, be decimated by the stress of "too many", or by disease which spreads more easily in crowded areas. At any given time, each species has limits beyond which it cannot go.

UNDERSTANDING D: Animals are a renewable resource and tend to produce more than their habitats can support.

Arizona's history gives us a textbook demonstration of this understanding: the North Kaibab is a large, forested plateau north of the Grand Canyon. Historically, Indians living in the area found far fewer deer to hunt than are now available. When European settlers came, they brought cattle, sheep, and other grazing animals.

In the enthusiasm of settlement, and with the help of 200,000 sheep and 20,000 cattle in 1887-89, the land was overgrazed. Grasslands were eliminated and slowly replaced by shrubs and small trees such as pinon and juniper.

This was deer habitat, as deer are browsers, not grazers, the deer population increased. The area became famous for its deer herds. In 1906, Theodore Roosevelt created the Grand Canyon National Game Preserve. Deer were protected; predators, removed - 781 lions, 30 wolves (the wolf became extinct on the Kaibab), and thousands of coyotes, bobcats, and eagles were killed. The deer herd, living in a rich habitat, with no hunting and few predators, exploded.

Too many deer was something no one understood. By the mid-twenties, there were perhaps 100 thousand deer. They destroyed their own food supply and shelter; deer died by the thousands. "Those that lived ate every leaf and twig 'til the whole country looked as though a swarm of locusts had swept through it. . . torn, gray, stripped, and dying. In many areas eighty to ninety percent of the forage was gone."

Enough deer survived those terrible times to supply seed stock for future herds, but the range did not substantially recover until the late 1940's. With recovery, the deer herds began to grow again in the early 1950's. It was almost a reenactment of the earlier tragedy. There were too many deer; the shrubs were hedged and trees high-lined (branches, twigs, and leaves eaten off as high as deer could reach).

In 1954-55 another die-off occurred; an estimated 18 thousand deer died of starvation (at least 50 thousand had died in one year in the '20s). The cycle began again - vegetation resprouted, and with food and shelter again plentiful, deer reproduction increased. But this time, the spector was recognized and in the '70s, heavy harvest lowered herd levels below the carrying capacity of the range. Today the range and deer habitat is in excellent condition. Deer herds are thriving and with today's awareness and management knowledge we can keep the Kaibab in parity with its deer.

Our pets and domestic animals are as prolific as their wild counterparts. If we take proper care of them, they live in quality habitat. When animals dwell within a satisfactory environment, they tend to reproduce more than their habitat can support.

Only good management of the animal resources prevents deer overpopulation on the Kaibab . . . or kitten overpopulation in your neighborhood.

CONCEPT NO. 4: Animal resources can be managed and conserved.

There is a very good correlation between domestic animals and wild animals that we seldom consider. We fail to remember that each animal, domestic or wild, needs exactly the same things: food, water, and shelter, and an arrangement of these three necessities within a space or territory appropriate for that particular animal. When these elements are present, and so arranged, we call it habitat.

A hereford cow, on an Arizona range, needs grasses, forbs, and brushy plants as food. The cow is a grazer and prefers the grass and forbs. Shelter from heat and cold can be found

around trees, large rocks, and brushy pockets. A mule deer, on that same Arizona range, utilizes many of the same plants that the cow does, except that the deer is a browser and prefers the forbs and brushy plants. The deer will find similar shelter to what the cow uses. Both need permanent water.

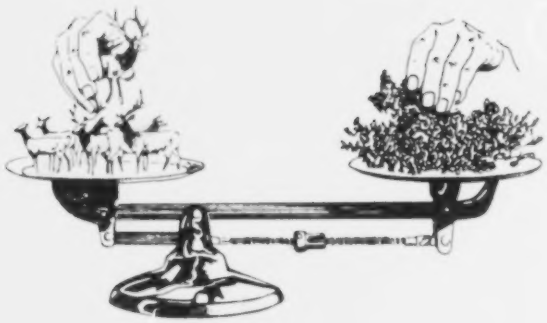
It may take seventy-five acres to support the cow and only twenty-five acres to support the deer. This difference reflects the fact that the cow needs three times as much food as does a deer and is also dependent upon the vegetative composition on the range. It may take more acres of land or less to support either deer or cow, depending on the quality of habitat. We might think of those acres as the space or territory required, though neither species is territorial in this sense.

Others of our domestic animals are very similar to their wild neighbors. If you watch quail, you soon realize their similarities to chickens. They scratch for seeds and eat insects; they need shelter for roosting and nesting; the males, called roosters, fight just like domestic roosters. Both nest, set on eggs for hatching, and care for the young. With domestic chickens, the hen does all the work. . . the quail, both parents set on the eggs and care for the young. Quail and chickens prefer to walk instead of fly. Their feet are designed for walking and scratching. They are closely related, both belonging to the order of Galliformes (the gallinaceaous or scratching birds).

So, if cows and deer are very much alike, and chickens and quail are closely related, perhaps we can better understand and manage our wildlife resources by thinking about these similarities and how we care for domestic animals.

If we want a healthy herd of cattle, we know that we must supply a healthy habitat for cows; if we want a healthy deer herd, we must do the same. Their basic needs are the same, only the specific details differ.

If we want to increase our cattle herd, we must supply more or better quality habitat. If we want more deer on the range, we must supply more or better deer habitat. The same applies for flocks of chickens or coveys of quail.



UNDERSTANDING A: Animals may be public or private resources.

Most pets and other domestic animals belong to individuals or families. Larger numbers of animals, such as horses, sheep, or cattle may belong to groups of people, companies, or corporations. A famous racehorse or a champion bull may belong to a group of people who invest in that particular animal.

Even these privately owned animals are regulated and controlled in some manner. Your dog must be licensed and have shots; cattle or horses may not be transported without permits; and cattle are slaughtered under prescribed conditions.

Here in the United States, wildlife belongs to the people. Our constitution says, "wildlife shall be the property of the several states" . . . which means that each state retains ownership of its wildlife and that the people of that state make the decisions as to how the wildlife resource shall be managed. Amendments to the constitution and treaties with Canada and Mexico have put migratory birds and rare or endangered species under Federal control.

Wildlife may also be reduced to private ownership. The most common way for this to occur is for a properly licensed hunter or fisherman to "take" (the legal term) such wildlife, following regulated procedures, and only during legal seasons.

Having wildlife in captivity is not commonly permitted. Permits may be issued for certain species, for specific uses, and under particular circumstances.

Laws and regulations control all useage of wildlife, and penalties are imposed for violations of those laws or regulations. For more detailed information on the possession of wild animals, contact your local Wildlife Manager, the Arizona Game and Fish Department, or obtain a copy of the regulation at a place of business which sells hunting and fishing licenses.

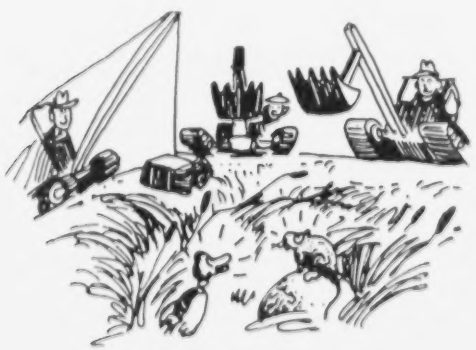
UNDERSTANDING B: Certain local, state, and federal agencies are charged with the management of animal resources.

The direct, on-the-spot, day-to-day management of wildlife is essentially the charge of the state's wildlife agency. In Arizona, this agency is the Arizona Game and Fish Department; in another state, the agency might be called the Division of Natural Resources, or the Department of Parks, Forestry, and Wildlife.

State agencies are primarily funded by the sale of hunting and fishing licenses and taxes on sport hunting and fishing equipment. Under the Pittman-Robinson and Dingell-Johnson Acts, these tax monies are allocated to the states by the U.S. Fish and Wildlife Service.

The U.S. Fish and Wildlife Service is the federal government agency which plays a supportive role to the states. It provides enforcement to control interstate and international transportation and importation of wildlife. This control covers the importation of living animals and such items as ivory, hides, furs, feathers, or other parts of wildlife. The Fish and Wildlife Service deals with migratory birds through the Migratory Bird Treaties with Canada and Mexico. This federal agency also provides research and other support systems for the states. For more information about your Fish and Wildlife Service or your Game and Fish Department and how they care for your wildlife, write or contact one of their local representatives.

Management of the habitat for wildlife is very complicated. The habitat may be managed by the Forest Service, the National Park Service, the Bureau of Land Management, the Bureau of Indian Affairs - all are federal agencies; or habitat may be managed by the State Parks Department or the State Forestry Department or by the owners of private lands, such as ranches and farms.



Habitat is wildlife, so this management is critical to the condition, the populations, and the very survival, of wildlife. So, in a sense, these agencies also manage wildlife, but this is not their primary function.

The management of domestic animals is also complicated. Each city, county, and state has laws and regulations which speak to licensing, commercial sale, transportation, health, and the humane treatment of your pets or livestock. There is the city or county dog pound, the state livestock inspector, the egg inspector, and others who deal with the management, control, and protection of domesticated animals.

Management of harmful insects in agricultural or forest areas may involve several agencies. Pesticides, that may effectively control the problem insect, may also cause other problems in the environment. In addition to the agencies, there are private groups and organizations which concern themselves with the humane treatment of all living things.

UNDERSTANDING C: Animal management programs are based upon socio-political considerations as well as biological.

Sound management of wildlife requires some knowledge of the biological principles involved in the particular situation. To make such a decision in regard to increasing or decreasing hunting pressure on a javelina population, there is need to understand the details of population dynamics: herd composition and reproduction, predation, survival of young, life span, as well as other factors such as hunt pressure and the quality and quantity of available habitat. This data is obtained through field study, analysis, interpretation, and compiled knowledge. Correct interpretation of these factors is the first step toward intelligent management.

But decisions are not always made entirely on the biological data available. Other considerations must be plugged into the formula. Attitudes of society, or even a minority part of the society often are a consideration.

Political pressures, too, often short-circuit management plans. In perfectly legitimate disagreements over priorities, wildlife often suffers. When a herd of pronghorn antelope occupy an area of Wyoming plains that are underlain with coal, it is almost certain that economics will demand that the pronghorn will eventually lose. Our needs for coal and other natural resources will dictate more and more the future of wildlife resources.

Wildlife workers live with the understanding that their best decisions founded in sound management practices may be replaced or reversed by a societal or political decision.

Domestic animals are fortunate; pets are usually lovingly cared for by their owners, and livestock is the livelihood of those who own cattle, sheep, and other farm animals. People, having been in the livestock business for thousands of years, know more about those animals than we know about the wild creatures. It is easier to study a pig than a javelina; a horse is easier to observe and understand than an elk.

But domestic animals also have those who "watchdog" their well-being. More humane handling in slaughterhouses, at racetracks, and at animal control centers has resulted from action from outside of ownership or management.

UNDERSTANDING D: Ethical actions involving animal life are the responsibility of society, but must start with the individual.

. . . if we accept the importance of the animal kingdom to our ecosystem.

. . . if we use and enjoy animals, we must give something in return.

It is important that we become aware of what effect our actions as individuals and as a society have on animals. As individuals, we can also oversee the proper care of domestic animals in our charge. By becoming informed and taking a stand on issues that affect our wildlife resources, we can work toward better management and understanding of a very valuable resource.

Those of us who are users of animals, whether ranchers, hunters, farmers, or fishermen, must remember that the wild portion of the animal resource is limited; it must be shared. We must obey the laws and rules that regulate our hunting and fishing and use of land. If we keep pets and other domestic animals, we must do the same. Those laws were made to protect and benefit the animal. Those laws, in turn, benefit us.

CONCEPT NO. 5: Animals are of value to man in many ways.

UNDERSTANDING A: Animals have consumptive and nonconsumptive values.

Consumptive values include those where we utilize the animal resource directly. Examples might include trapping wild animals for fur, raising animals for food, or hunting. Nonconsumptive values of wildlife might include bird watching, wildlife photography, or other activities that do not directly harm the animal. Pet owners spend millions of dollars a year in enjoyment of their animals. In Arizona, millions of dollars are generated each year through consumptive uses of the state's animal resources. In 1982, over 122 million dollars were generated by hunters and fishermen utilizing portions of the wildlife resource. Over 682 million dollars were generated through the sale of range and feedlot cattle in 1979. The consumptive uses of wildlife and domestic animals can have a dramatic effect upon the overall economy of a given geographical region. Throughout history, humans have utilized wildlife or domestic animal resources for food, shelter, clothing, and other specific needs. Human utilization of animal resources can also create direct and indirect vocational opportunities for people. These include ranchers, farmers, butchers, wildlife managers, horseshoers, feedstore owners, veterinarians, and other similar occupations. Consumptive wildlife-based activities such as hunting and fishing, provide Americans with over a billion days of outdoor recreation each year. Nonconsumptive activities, relating to wildlife, likewise, provide millions of days of recreation annually.

UNDERSTANDING B: The ties between humans and animals vary, but are expressed in religion, life styles, art, music, drama, literature, and other means of creative expression.

The relationships that humans have to animals will vary from person to person and culture to culture. Many of these relationships are a function of how a society has developed and the kinds of animals it is exposed to. However, throughout all cultures and societies is a consistent relationship between animal life and creative expression. One need only go back into religion, literature, music, and drama, of past and current societies, to see how important animal life is and has been. In Arizona, the Hohokam Indian utilized many animal forms in their petroglyphs. The legend of Rome used the eagle as a standard. The Navajo have a whole series of stories centered around the coyote.

UNDERSTANDING C: Humans find inspiration and satisfaction through the ownership, study, and observation of animals, or simply through knowledge of their existence.

To get an idea of just how important animals are to our existence, one need only look around to see how close animals are to us. The most obvious example is in the pets we own. In the United States, pets are an integral part of our society. Millions of dollars are spent annually on the care and feeding of the animals we keep around us. Few pet owners would argue that their dog, cat, horse, or other pet provides them important companionship, enjoyment, and love.

For many people, the observation and study of animals is an important aspect of daily existence. Memberships in the National Audubon Society, National Wildlife Federation, American Humane Association, and other animal-oriented groups, include millions of individuals in our society. These people gain a great deal of satisfaction from contributing to, and learning from, these groups.

There are many kinds of animals that we as individuals may never see. Yet their existence provides a form of satisfaction. For example: for many people the knowledge that we have many mountain lions that live in Arizona is important. Even though most of us will never see a mountain lion in the wild, we value the existence of these animals and will often contribute time, money, or other things to see that they will continue to survive.

UNDERSTANDING D: Study of animal needs and behavior can give us insight into some important human needs and behavior.

The human animal, the wild animal, and the domesticated animal all tend to have the same basic needs and show some of the same behaviors under the same conditions. By studying the behaviors and needs of animals other than ourselves, we can often gain important insights into our own behavior. There have been extensive studies done of primates (monkeys and gorillas) which show how human beings might react in situations where they are removed from any contact with others of their own species, or when removed from their mothers at very young ages. Psychologists have used rats in studies to determine how individuals might react in high-density population situations as occur in slums and other inner-city areas.

Some forms of animals, because of their close physiological nature to humans, are used to test drugs and other medical procedures. The grizzly bear is able to exist with extremely high levels of cholesterol in its blood. A number of studies are currently underway to determine how the bear can do this, with the hope of helping human cholesterol problems.

UNDERSTANDING E: Animals have social, political, scientific, and ecological value.

Most human societies and cultures have developed in the way they have because of the environmental factors that produced the types of plants and animals that live in the area. Because of our close dependence upon animal resources, they have often influenced alliances and conflicts between nations. Most nations and governments tend to have different policies and philosophies relating to animal ownership, protection, and habitat management. Because of these differences, nations will often clash over specific animal-related incidents. While some of these clashes might be minor in nature, some have almost lead to war. An excellent example of this was the fur resources of Canada and Alaska and the competition between the United States, Russia, and England for these resources.

Animal issues continue to play an important role in the environment in which they occur. Their contributions to the diversity and balance of the ecological system are essential.

Because of the close ties of animal life to an environment, one of its primary values is that of being a barometer of the overall environmental quality. The study of the interactions of animal life and ecological systems, both past and present, can help us understand how these systems operate and help us to avoid or lessen our impacts in the future. As we learn more and more about animal resources, we see that they are more and more valuable to our own existence. Often they can give us insights into very vital questions of our own survival.

HUMANS IN THE ENVIRONMENT

BACKGROUND

Humans are an integral part of the total environment which we call the biosphere. They are impacted by natural events which occur within this sphere. Our actions also impact directly on the rest of the natural resources found in the biosphere and discussed in this guide.

As a result, this chapter could be both the first and last in this guide. It might be first because the rest of the material would not have been developed if we were not here. It is placed last because everything we learn in the rest of the chapters helps us to understand our role and relationship to this biosphere that we call earth.

For every activity that is contained in the activity section, you could probably ask yourself and your students: "How does this affect me?", "How do I affect it?", and "Why is it important to me to understand this?". If you did, then you would probably not need this chapter. But, this chapter seeks to sort out and present those concepts and understandings which we felt would focus attention on why humans should be aware of the natural resources in the biosphere.

The activities that have been developed to help you teach this information are broad and time-consuming. For the primary grades they may seem advanced, but we hope you can use the ideas in short discussions. Any time that these activities can be supplemented with or replaced by a local issue with which your students are familiar, you will probably increase the learning that takes place. Remember that the most important thing is to help your students accept and evaluate the role of humans in the environment. The goal is not to place values such as good or bad on these actions, but to allow each student to draw his or her own conclusions and to realize their dependence on these natural resources.

CONCEPT NO. 1: Humans live within the earth's biosphere.

The biosphere of the earth is the only known natural home for humans and the other living things found here. However, it is not unusual for humans to take for granted those basic requirements that are necessary for life. This is probably true because we are able to provide these necessities more easily than earlier generations or in larger quantities than more primitive societies. In addition, fewer people are involved in producing each of the basic requirements for life and, therefore, many people only have to go to a store to get the things they need.

If nothing else, the exploration of space served to reinforce the knowledge that the earth's biosphere is both finite and unduplicated within our solar system. Therefore, it is essential that we understand the importance of the earth's resources in supporting life, the limitations of the resources found here, and our role and impact on the wise use of these resources. We need to remember that we have only one natural home and that is the earth.

UNDERSTANDING A: Like other living things, we depend upon the biosphere for the basic requirements of life.

Every living thing that humans are aware of needs certain basic requirements in order to sustain life. Humans are no exception! We require an energy source, our food, in order to keep our bodies functioning. Our food supply depends on plants and animals as its source. Water is essential as a primary liquid for many human activities. Many of these are described in the Water Chapter. Shelter may not protect us from predators as it does many animals but it is necessary as a protection from the climate. Things geologic and plants supply most of the material required to build the buildings in which we work and live. The atmosphere surrounding the earth provides us with the oxygen that our bodies need. Finally, each of us requires a living area in which we can move about in our daily activities. Some of these basic requirements can be found in space but most of them have, so far, only been found on earth in the proper combination to support us.

UNDERSTANDING B: The biosphere includes many environments in which humans live.

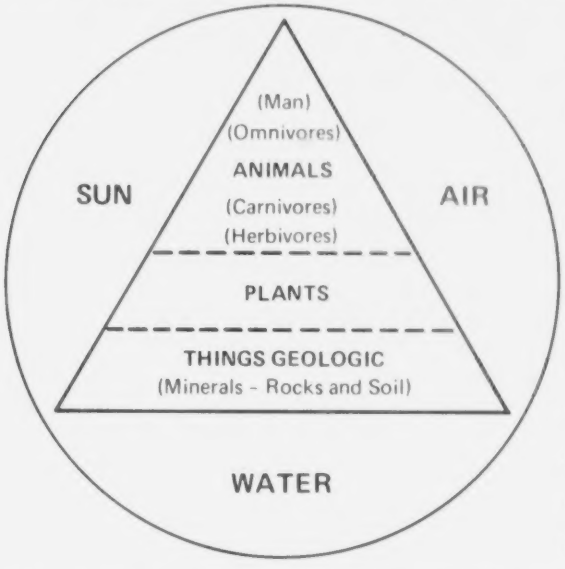
Earlier chapters in this guide, particularly the ones on "Climate", "Things Geologic", "Water", "Plants", and "Animals", emphasize the fact that the earth is not uniform. Many factors create differences that produce unique environments in which only certain plants and animals live. It is important for us to recognize these differences because of their impact on our lives and the impact we can have on them by our actions.

Even more important to realize is the fact that while most living things have adapted to the environment in which they live and as a result are limited in their distribution, humans are capable of living in most of the environments found on earth. We either modify our needs and actions to adapt to the local conditions or we import materials that allow us to create acceptable living conditions for the area.

Within Arizona, for example, there are human communities in almost every plant life zone identified in the "Plant" Chapter. The only exception is in the alpine tundra which is limited to the top of the San Francisco Peaks.

UNDERSTANDING C: We live at the top of a pyramid as part of the animal kingdom.

The figure illustrates in a conceptual way the position of the human within the earth's biosphere and our relationship to the other basic requirements of life. Although the sun, air, and water are shown as a sort of envelope around the earth for the purpose of this illustration, earlier chapters of this guide provide a more accurate description of their true relationship to and in the earth's biosphere. The oxygen that we breathe is part of the atmosphere. This is one of the three spheres which create the biosphere and in a truer sense does form a circular envelope around the earth. If we eliminate any of these three basic requirements, life as we know it would not exist here.



Within the pyramid, each layer is dependent on the layer below it for its existence and in turn supports the layer above it. Therefore, if change occurs in a lower layer, a change of some sort will also occur in the layers above this layer. Some of the most graphic examples of this cause and effect relationship are best seen following an earthquake or volcanic eruption. These may change the soils in the area or affect the quantity or quality of the water. In addition to the immediate impact on the plant and animal life of the area caused by the geologic event, the change in soil and/or water creates some longer term changes in the plant and animal life.

By noting the human position in this pyramid, we can better understand the highly dependent nature of our existence here on earth. As the top layer of the pyramid, humans somewhere on earth are directly impacted by any change in a lower layer. Other examples of the relationship between the human layer and the basic layers which support our existence are given in Concepts 2 and 3 of this chapter.

CONCEPT NO. 2: Humans exert control over and are controlled by the natural environments in which they live.

Every homeowner in Arizona is acutely aware of the change of seasons. For each of us it means that our energy use will either increase or decrease depending on whether we live north or south of the Mogollon Rim. In the Salt River Valley, the coming of winter means

that the "snowbirds" will soon arrive and that cold air inversions coupled with the additional cars moving about the valley will often result in severely reduced air quality. Without a doubt, the environment in which people live does influence their actions.

On the other hand, we use energy to heat and cool our buildings in order to control the environment. We remove native vegetation and replace it with houses and streets. We dig below the surface to extract minerals that will produce electricity and carry it to our homes. After removing the minerals, we leave the rest of the rock materials in large piles that cover up the plants and soil and change the animal life in the immediate area.

Humans are the only living thing on earth that are capable of purposefully changing their environment. Our ability to gain knowledge and create change permits us to adapt our environment to our needs instead of adapting to the natural environment. As a society becomes more "advanced", it spends more time and effort modifying the local conditions to create an environment that provides them with those items which they feel make life easier. However, even the most primitive human society builds shelters and warms themselves with plants they have harvested. The major difference between these two groups is the amount of control they exert over their local environment.

UNDERSTANDING A: The local environment has an impact on the local human population.

Climatic change by seasons or over a long term of several years is one of the most obvious effects of the local environment on human populations. A series of dry years or just one winter with a much lower than average snowfall causes serious concern for many Arizonans. The reduced production of range plants reduces rancher incomes. Water levels in our lakes which depend on spring runoff to refill them begin to drop, and all those who use this water must begin to make other plans for irrigating or serving the needs of a local water system. With the reduced snowpack, those people who run skiing enterprises experience reduced incomes.

In Pima and Santa Cruz counties, where all of the water supply comes from groundwater sources, large cities like Tucson are being forced to seek solutions that will ensure future supplies of water. In other parts of Arizona, where groundwater is not available and precipitation is limited, many people must haul all of their home water supply from water sources many miles away.

UNDERSTANDING B: Many humans reside and work in fabricated environments.

Most people in Arizona live in a community which we have created by building homes and businesses and constructing roads. We bring food, clothing, electricity, and many other items in to support the population. All of these products and buildings are made from one of the basic requirements of life but many do not exist in the locality where we live. The human species is the only living thing on earth which is capable of doing this.

UNDERSTANDING C: We feed and clothe the world's population by increasing the production of selected plants and animals.

Humans have always depended on plants and animals for their food and clothing. Originally we were gatherers who used only the plants and animals which were native to the area in which we lived. However, as the population grew, humans began to select and cultivate certain plants from which they could produce a larger quantity of food supplies. Animals were tamed and kept for their ability to produce milk or meat, and these species were herded for that purpose. As our knowledge grew, we began to breed the more productive plants or animals and our capacity to produce increased.

A study of Arizona history provides an excellent example of the development of our ability to practice agronomy and animal husbandry. Beginning with the Hohokam Indians and tracing the changes in human occupancy in Arizona, we can find everything from primitive gatherers whose societies were limited by the natural environment's capacity to produce food supplies to today's high technology society in which plant and animal breeding is a careful science.

UNDERSTANDING D: We produce many of today's "necessities" for life from things geologic and water.

If we look around any room or building, we find many products that are manufactured from geologic materials. Door knobs, chairs, light fixtures, wire, cars, and many other items are there because we have developed the skill to mine minerals and process them into products which we now consider as necessities for life. Many other items, such as energy, glass, bricks, and concrete, are also made from things geologic. Water is an essential compound used in the production of most of these products.

The miner is one of the primary characters in Arizona history, playing an important part in the settling of this state. It is because of our diverse and rich geology that people originally moved here and why mining has continued to be an important part of Arizona's

economy. The products of this important industry are found in every business and home in the state.

UNDERSTANDING E: The availability and distribution of renewable and nonrenewable resources influence our lives.

As discussed in the "Water", "Things Geologic" and "Soils" chapters of this guide, these basic requirements for life are not distributed evenly over the earth. In Arizona, humans have spent large sums of money to control surface water or pump groundwater and to move it from one location to another to meet their needs. As the groundwater levels have dropped and water quality has been reduced, we have invested both money and time seeking solutions.

Because of the presence of deep, tillable soils and a reliable source of water, early settlers located along the Salt, Gila, and Colorado Rivers. To the uninformed, these seemed to be rather poor areas to live because of the inhospitable environment, but, because the resources were there to produce bountiful crops, it was here that people came and settled.

In Lake Havasu City, the soils were capable of supporting homes but were poor for intensive landscaping. As a result, in order to create parks and a golf course, the developers were forced to import soil material and large quantities of organic material.

One of the problems facing our country today is the imbalance of trade caused by our importing large amounts of minerals, including petroleum, from other countries. Because we do not produce enough materials that are sold to other countries, we must pay for these minerals instead of trading for them. In addition, we must protect these source countries and maintain a political relationship with them in order to ensure our supply of their products. The pressures on our country created by this need are a tremendous influence on our lives.

CONCEPT NO. 3: Humans affect natural cycles in the environment.

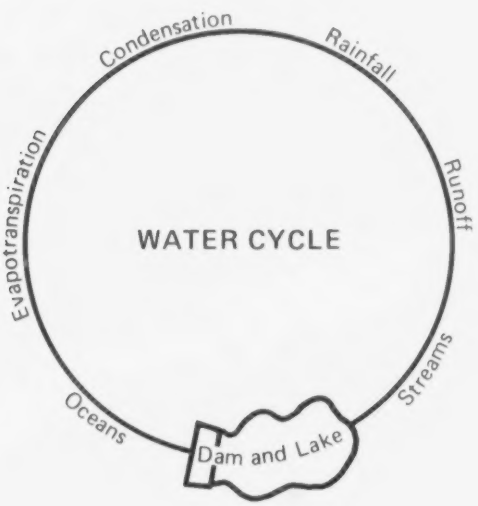
A natural environment is a complex system of cycles and food chains, many of which were described in earlier chapters of this guide. As long as a local human society lived within an environment and obtained most of its necessities for life there, our impact on the environment was not drastic. However, as our technology and demands increased, we began to have a greater effect on natural cycles. Some of our actions caused immediate

changes, such as when a subdivider stripped an area bare before beginning to build. Other actions took much longer to create problems, such as the gradual accumulation of DDT which finally worked its way up the food chain of the osprey and caused a serious decline in the population. The first example was also a much more localized problem than the second.

The old adage, "out of sight, out of mind", governed America's treatment of resources for many years. It wasn't until the rate of production and population densities increased that people began to recognize the consequences of our action. Today, it is important for us to remember that every action we take produces a reaction in the life around us and that only humans will make the judgment as to whether the result is good or bad. This is referred to as "trade-offs" and it is a natural occurrence that we must be aware of and evaluate each time we decide to take an action. Other species will only go away or move into the new environmental conditions that we have created.

UNDERSTANDING A: We interrupt some cycles or food chains.

A historic example of how humans affect food chains is the plowing of the Great Plains. This seriously reduced the amount of plants for the buffalo and other grazing animals native to the area and, along with severe hunting pressure, resulted in a large decrease in the number of these animals. Also, by eliminating the native plants, the mineral cycle was disrupted and serious soil erosion became a common problem. In exchange for this change in plants and animals native to the area, we created one of the most productive food-producing areas in the world.



On a local level, similar changes in food chains have occurred as we have built cities, developed mines, or moved from desert to large scale farming operations in Arizona. In order to accomplish these changes, it has been necessary to control water. This has frequently been done by the use of dams. As a result, the river becomes a lake and the downstream flow is changed. The area as a whole becomes more productive for the humans living there but the native plants and animals must change or adapt to a whole new set of conditions.

UNDERSTANDING B: We transfer resources from one place to another.

In 1980, Arizona produced 65.9% of all the copper in the United States. Some of this copper is now in homes throughout the U.S. and some of it is in the cars that zip along our interstate system. Arizona ranked fourth in 1982 in the production of fresh market vegetables. A large portion of these vegetables obviously ended up on the tables in many other parts of the country. These are prime examples of how our modern American society moves large masses of materials from their point of origin to many other locations. This results in a very complex and energy consumptive lifestyle that is becoming increasingly difficult to maintain.

Each time we transfer one primary resource out of Arizona, we send with it some secondary resources that were used in its production. In the case of copper or vegetables, this includes a certain amount of water which was used in processing copper or irrigating crops. In the other direction, Arizonans import many resources produced in other parts of the country or world. This shifting of resources is another way in which we impact natural cycles.

UNDERSTANDING C: We introduce waste products into local natural cycles.

The old adage, "out of sight, out of mind", governed America's treatment of resources for many years. Factory or home effluents dumped into a river soon disappeared downstream. Smoke from processing plants or home heating rapidly dissipated in the air currents. As the rate of production and population densities increased, we have become more aware of the problems in disposing of our wastes. As our technology increased, these wastes became more toxic and had a larger potential for damaging the environment and all living things. Many of these are chemicals that will leach out of landfills and end up in the watertable. It appears that our modern, high-density, high-production society will continue to produce waste products that will degrade our water, air, and land resources unless they are handled properly.

Humans also introduce products into a natural cycle as part of the basic food-producing process. A well-documented example of this type of activity was the use of DDT in agricultural production and its result on the population of several fish-eating bird species. Fertilizers and pesticides play an important role in our ability to produce the large quantities of food necessary to sustain the world's population. However, when these are used in excess or on eroding land, part of these chemicals are moved from the field to other areas where they often create adverse effects.

UNDERSTANDING D: The quality and quantity of resources change as natural cycles are modified.

Each time we affect a natural cycle or food chain in one of the ways discussed above, we impact either the quality or quantity of the resources. By adding water, seed, and fertilizer to the desert soils, we dramatically increase the production of plant materials that we can use for food, fiber or forage. Although we get an increase in the production of plants, in many areas of Arizona we also get a reduction in the groundwater table. Also, most of the fertilizer we use has been imported from some other state or country.

When we dam a river, we have the potential to produce more energy, to do more boating and waterskiing, and to reduce flooding. However, we also lose more water to evaporation and, in Arizona especially, we lose areas of riparian habitat, a limited resource.

A new community produces more homes and attracts new industry, which helps employment. It uses many tons of concrete, brick, wood, asphalt and other building materials. However, it covers over the land so that it can no longer be farmed or grazed. It yields more waste and changes the animal life found in that area. Each time we change an area, we create trade-offs. These must be evaluated carefully to determine whether the final environmental changes that occur are what we want to happen.

CONCEPT NO. 4: Our use of resources changes as our knowledge and demands increase.

All animals except the human species slowly adapt to changes in their environment or gradually become extinct. It is the nature of humans, however, to accept challenges as obstacles to be surmounted. As a result, most human societies seek to find new and better ways to do things. This attitude leads to inventions and new uses of resources. The space program is a good illustration of how many new products have become part of our way of life because we sought to overcome a barrier. New metals and sophisticated communication equipment, special food products and packaging, and better ways of air and water purification have all come about because we wanted to put people in space.

Similar changes in both resource use and the genetics of plants and animals have occurred in agriculture as humans sought to improve our production of food and fiber. Plant breeding continues to provide new varieties of crops that are either more productive or more disease tolerant. Between 1967 and 1977, irrigation systems were installed on 15 million acres of cropland. Most of this was in states where irrigation was not historically

used. Today, all but two states have some irrigated acreage and 17 states have at least one million irrigated acres. In 1982, Arizona ranked 11th in total irrigated acres.

UNDERSTANDING A: New technology increases our ability to make changes.

Many of us have enjoyed films of wildlife managers using radio-tracking collars with various kinds of animals. The excitement of working closely with wildlife is easily transmitted. More importantly, the information gathered has allowed us to better understand the needs of other species. With this increased knowledge we are able to make more learned decisions in managing the environment in which that species lives.

The traditional picture of the old prospector and his burro combing the Arizona mountains for gold, silver, or copper has created a lasting impression of independence and self-sufficiency. However, today's prospectors often do their work from an airplane using modern scientific equipment that will detect certain minerals below the earth's surface. Above the airplane, satellites orbit and take pictures of the earth's surface. These electronic photos are used for mapping resources as well as detecting crop diseases or forest fires in remote areas before they become widespread.

New technology allows us to move mountains faster, build higher and faster, and recycle many things that were thrown away not too long ago. The speed with which we can make changes has created a society that is often impatient. As a result, sometimes we do things before we consider the consequences and we make new problems. On the other hand, our advanced technology and knowledge base often provide the solution to these problems much more rapidly.

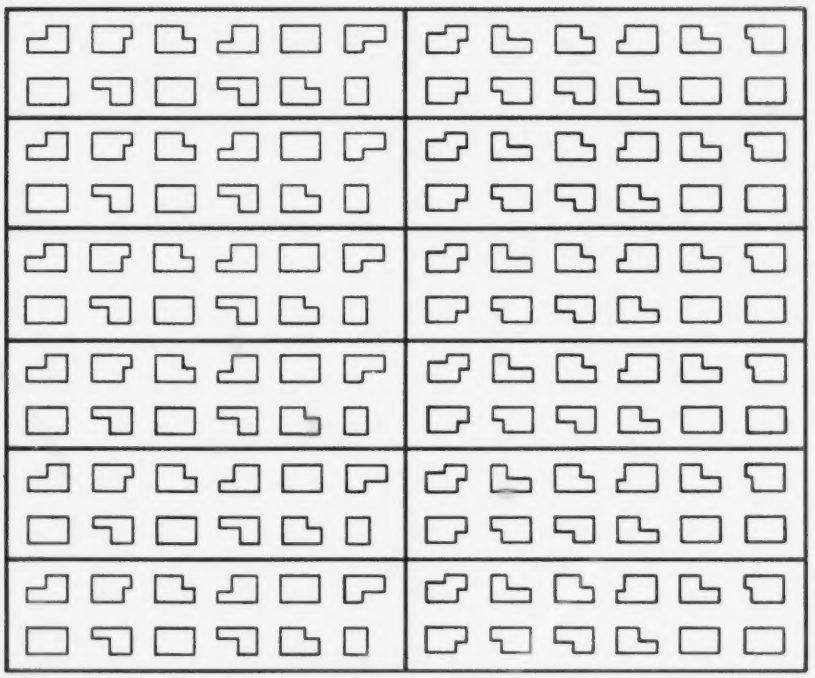
UNDERSTANDING B: Population growth creates more demands.

The idea of "keeping up with your neighbor" has become a part of the American lifestyle. People desire a better way of life or more things, especially if it's in their neighbor's garage. The worldwide population growth, coupled with the desire for a better style of life, results in more demands on the basic natural resources from which we get the material to produce these "things". In America, this desire for things is further promoted by one of the most sophisticated advertising systems ever created. As the American and world population continues to grow, the demand for new products and the basic needs that sustain life will continue to grow.

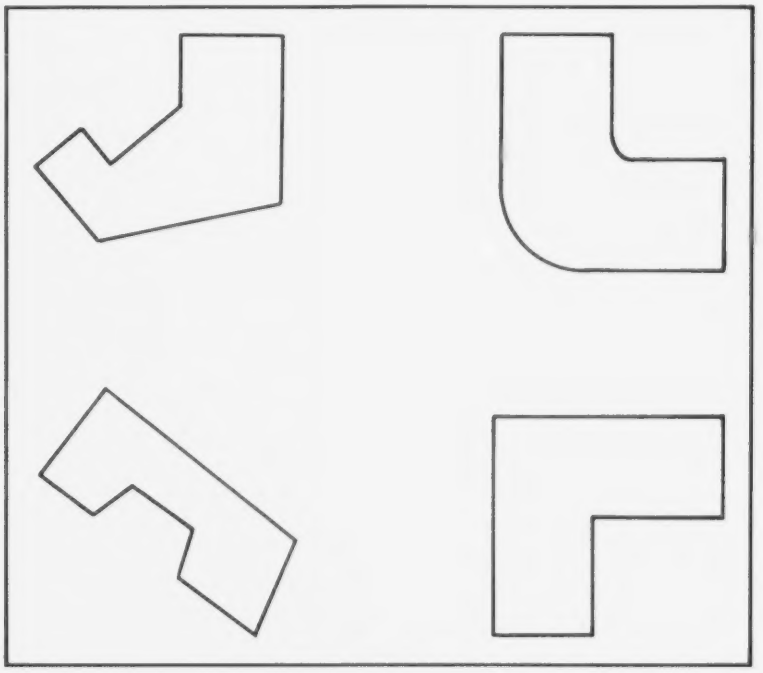
Besides the need for more homes, cars, food, and clothes that a growing population requires, we are also experiencing a growing demand for recreation. In 1981, more than nine million people visited Arizona's national and state parks. Four million people flew into either Phoenix or Tucson and 1.3 billion gallons of vehicle fuel were consumed. More than 100,000 boats and 65,000 travel trailers were registered. Tourism in Arizona is second only to manufacturing in the production of income. In 1980, more than 3.6 billion dollars were spent on tourism (recreation). Every visitor to Arizona needs water and food, even if they do no more than enjoy the aesthetics. However, others want to experience some of the other activities that are more resource consuming. This creates a temporary population growth, during certain times of the year, that adds to the demands made on Arizona's environments.

UNDERSTANDING C: Economic and social decisions often affect the environment.

A decision to develop 40 acres with residences for 160 families can be accomplished in several ways. The new subdivision may have four one-family houses to the acre instead of a complex with 15 dwelling units to the acre because the individual homes sell better. In one case, each family has a yard they must maintain and, in the other, the 160 families have 29 acres of common open space that can be used in several different ways. If the land to be developed is desert or cropland, we lose that environment and create a new one with less flexibility. When the paving and building is completed, there is less soil area to absorb rainfall and, therefore, more water can runoff.



Houses in typical subdivision.
4/acre; 144/40 acres.



Four condominiums on about 11 of the 40 acres. The rest is open space.

Grazing domestic livestock is an important use of Arizona's land. With increased knowledge of the management of range resources, ranchers have found that certain improvements will allow them to conserve the forage plants as well as run more cattle. Such things as cross-fencing to allow better control of the animals and the development of permanent water are investments that have positive payoffs. In dry seasons, the supply of water not only benefits the livestock but also wildlife. However, cross-fencing may obstruct or change wildlife movement and it definitely affects people. In both cases, the decision to improve range management results in a change in the environment on that ranch.

CONCEPT NO. 5: Knowledge about the environment allows us to manage it better.

Just as a school cafeteria manager knows that serving eggplant will probably result in a full garbage can, knowledge about how and why resources do what they do will allow us to manage them better. In an open, well-managed forest of ponderosa pine, it is possible to produce saw timber more rapidly than in an over-populated stand. We know that each tree needs a certain amount of energy from the sun, geologic area for root development, and limited competition for the available water in order to grow. If our management objective is to produce lumber, our solution is simply to allow each selected tree to receive the optimum amount of sunlight, root space and water it needs.

A deer or elk requires a given amount of certain kinds of forage in order to live and produce offspring. If too many animals are grazing the same area, some of them must die in order for some to survive. This is a given fact of life and wildlife managers use it to determine how many animals can be harvested to balance forage production with animal numbers.

UNDERSTANDING A: The environment is complex and interrelated.

Although the examples given above seem simple and straightforward, we know that the production of forage varies from dry to wet years but we don't always know whether the coming year will be wet or dry. If the local rancher decides to graze more sheep in a good deer wintering area, the amount of forage left for the deer will be less. Many plants that deer browse grow best in the spring and fall rather than the summer. Therefore, if rain or snowfall is low at that time of the year, there will be less forage even if the summer rainfall is much higher than normal. We must recognize that it is often easy to identify a cause and effect relationship in the environment but that it often takes a great deal of additional knowledge and searching to pinpoint the exact reason something happened.

A first step in teaching environmental awareness and understanding is to admit that it is a complex and interrelated subject. Therefore, we may not know all the answers to why something occurs without taking plenty of time to observe and study a situation. The key then is to acquire information in small doses and to compare what we know with what we are learning so that the environmental jigsaw puzzle will begin to fall into place.

UNDERSTANDING B: We need to recognize our impact on the environment and accept it.

From conception through birth and on to death, every living thing has an impact on the environment. Humans, because of their high mobility and ability to move large amounts of materials from one spot to another, have a much greater potential for affecting the environment than any other species. Until such time as we are able to do without food, clothes, and houses, we must accept the fact that our actions will create change in the environment. Whether this change is good or bad depends on our personal viewpoint and the responses it elicits in others, but we are stuck with the fact that change it will.

UNDERSTANDING C: We can plan for wiser use of natural resources and reduce our impact.

Most living things react to outside stimuli in a manner that is fairly predictable and constant for a given species. A startled animal usually runs to escape and seek cover from any potential danger, although this often does not hold true for grizzly bears and other more daring predators who may attack rather then retreat. Place a fly on a Venus flytrap flower and it will snap closed. Cut the leader out of the top of a pine tree and one of the other topmost branches will turn upward to take over the job.

The one potential exception to this type of action-reaction situation is the human species. With the ability to think ahead and evaluate the effects of our actions, we have the capability of planning to produce a desired result. Few people would purchase a truckload of 2x4's and attempt to build a house. They would first develop or buy a set of plans and then purchase just the materials they need. However, because we also tend to be lazy, people frequently become creatures of habit in order to reduce the amount of thinking they must do. The person who follows the same route to work for one, two or ten years is fit to be tied when road construction or other interference makes him/her follow another route. The hunter who finds the road to his/her favorite hunting spot suddenly blocked by a locked gate is often not too docile in his/her reactions. It is frequently our habits that cause us to do damage to an environment. It often seems easier to do things in the same way than to change, even though we may see that a change would be beneficial.

We are capable of evaluating our impacts on the environment and changing our ways in order to create a balance that will permit humans as well as most other living species to live a satisfactory life on earth. We can reduce the severity of our impacts on the environment if we take the effort to plan our use of both natural and human-made resources. But this means we must make a commitment of dollars and time to research in order to increase our knowledge about this complex biosphere in which we live. Each individual must accept the responsibility to become more aware, better prepared, more caring and more committed to the care of the environment in which we live. We do have a common goal if life is to continue with a minimum of environmentally caused misery on all living things. This guide has been dedicated to helping you and your students achieve these results.

CLIMATE

BACKGROUND

The state of Arizona measures 300 miles north to south and 250 miles from east to west. Within these boundaries, there is a rich variety of ecological domains that are matched in few other states. The geologies, plants and animals in each of these regions differ from each other -- so do the activities and lifestyles of man. Altitudes range from about 350 feet above sea level near Yuma to over 12,000 feet at Humphrey's Peak. Summertime temperatures can soar to over 115° F. in the deserts to -40° F. in the high country during winter. Plant life ranges from the barren sand dunes near Quartzsite to the pine forests in the White Mountains. Climate is pervasive; it controls the soil types, the landscapes, plant and animal life, as well as strongly influences man's activities. These effects are detailed in the appropriate chapters. Perhaps less well known is the wide variety of climates that accompany these more visible changes. Also less well known is the response of climate to the local environment.

The terms "weather" and "climate" are sometimes not clearly differentiated. Both terms look at the state of the atmosphere, but from different perspectives. The term "weather" looks at the state of atmospheres at a given place and at a given moment in time, or at the outside, the state of the atmosphere for a limited time and over a limited area. In response to the varying influences from the sun and the earth, the air moves freely over the earth's surface. Consequently, the physical characteristics of the air are continuously changing.

To adequately describe the weather, instrumental measurements are required. The most important measurements are: (1) air temperature, (2) pressure, (3) wind direction and speed, (4) the amount of moisture in the air, (5) cloudiness and occurrence and type of precipitation, and (6) the amount of precipitation since the last measurements. Meteorology, as the science of weather, applies the laws of physics to the atmosphere to explain the observed weather phenomena. Meteorologists are continually refining techniques to improve weather forecasting.

Climate, on the other hand, is the summary of all the complex weather influences. It summarizes the components of the weather, such as temperature and rainfall, as well as their distributions, both in time and space. Climate describes the conditions most likely to occur over an area during a given time period. We say, "the average temperature at Flagstaff during July is 66.1° F.," or "the average wind speed at Tucson during January is

7.8 miles per hour." Climate is thus geographical in nature; it defines the most probable weather conditions which are likely to be observed in a given area during a given time. As such, it is closely associated with changing events in the environment, and becomes a valuable tool in the explanation of these conditions.

CONCEPT NO. 1: Climate is affected by several factors.

Climate is affected by several factors, or controls. If the earth's orbit were perfectly circular, and if the earth's axis were perpendicular to its orbit, then every latitude of the earth would experience the same length of day and receive the same amount of solar energy every day. If, also, the surface of the earth were uniform and smooth, then at every latitude the solar energy would be uniformly utilized. The result would be the same weather at each latitude, a very monotonous situation.

We are spared this dullness by a number of factors. These are termed "climatic controls", and affect both the weather and climate of a place. These factors are: (1) the intensity of solar radiation and its variation with latitude and time; (2) the albedo, or reflectivity of the earth's surface; (3) the distribution of land and ocean, and (4) topographical features. In addition, several other factors may influence a local climate. Such factors will include vegetation, small bodies of water and man's activities.

UNDERSTANDING A: Temperature decreases with altitude.

It is common knowledge that, generally, the temperature of the air drops as the altitude increases. For example, the annual mean temperature of Winslow at 4,895 feet above sea level is 54.9° F., while Yuma, at 194 feet, has an annual mean temperature of 73.9° F. About halfway between, Tucson -- at 2,584 feet -- has an annual mean temperature of 68.0° F. Between Winslow and Yuma, the mean temperature of the air drops with altitude at a rate of (closely) 4° F. per thousand feet.

Offhand, one might suspect that since the atmosphere does filter out sunshine, the higher elevations would experience warmer temperatures. Certainly one sunburns more rapidly at higher elevations. Certainly in a heated room air at the ceiling is generally warmer than air at the floor. We must, therefore, ask, "Why does the air cool with increasing altitude?"

In a heated room, air at the ceiling is generally warmer than the floor. This is because the warm air rises and is trapped by the ceiling. Without a ceiling the warm air would

continue to rise and expand as it met lower air pressure. If dry, this rising air would cool at approximately 5.5° F. per 1,000 feet. If it were moist air it would cool at approximately 3° F. per 1,000 feet. The "average" would be about 4.5° F. per 1,000 feet.

UNDERSTANDING B: There is a general circulation of the atmosphere.

Because of the earth's spherical shape, the top of the atmosphere in the equatorial regions receives more solar energy than the polar regions. At the earth's surface, this disparity is enhanced by the greater thickness of the atmosphere that the solar beam must traverse in the polar regions. As a result, the equatorial regions are much warmer than the polar regions. The oceans and atmosphere attempt to equalize the temperatures by their circulation systems.

Latitudinal averages over a period of years define an average atmospheric wind distribution. The polar easterlies extend from the poles to about 60° latitude, the trade winds from about 30° latitude to the equator, and the westerlies lie between these two broad wind belts. The wind belts follow the sun, north and south, during the year.

Arizona is situated such that, during its winter season, the westerlies dominate its weather patterns. After the major wind belts migrate northwards in the summer, Arizona is located primarily under the influence of the Atlantic subtropical high. The primary wind flow is therefore from the south. The change between the wind patterns is relatively fast, changing from a westerly to a southerly flow in about May, and back to westerly in about October. The alternation of wind patterns has a profound effect upon Arizona's weather and climate.

UNDERSTANDING C: The distribution of land and water strongly affects the local climates.

Due to a number of factors, bodies of water are more conservative than land surfaces with respect to temperature changes. Water has a higher specific heat than land; more heat is required to raise a pound of water one degree than a pound of soil. A land surface is opaque to solar radiation; radiation falling on a land surface is absorbed and converted to heat at the surface, whereas radiation can penetrate several hundred feet through sea water, and spreads its heating through the same depth. A land surface is relatively stable, whereas water is a fluid. Through wave action, turbulence and currents, heat can be carried either vertically or horizontally.

The effects of a water surface on climate can perhaps best be described by considering San Francisco and Wichita, Kansas (see Figure 1). Both locations are at the same latitude and so receive the same amount of solar energy at the top of the atmosphere. Both also have an annual average temperature of 57° F. The annual range of temperature at Wichita, however, is about 5 times larger than at San Francisco. Figure 1 shows the average monthly high and low temperatures at San Francisco and Wichita. In each month, the average daily range of temperature, the difference between the high and low temperatures, is much larger at Wichita than at San Francisco. Wichita is said to have a "continental" climate, while San Francisco has a "maritime" climate. Maritime climates have smaller daily and annual ranges of temperature than continental climates.

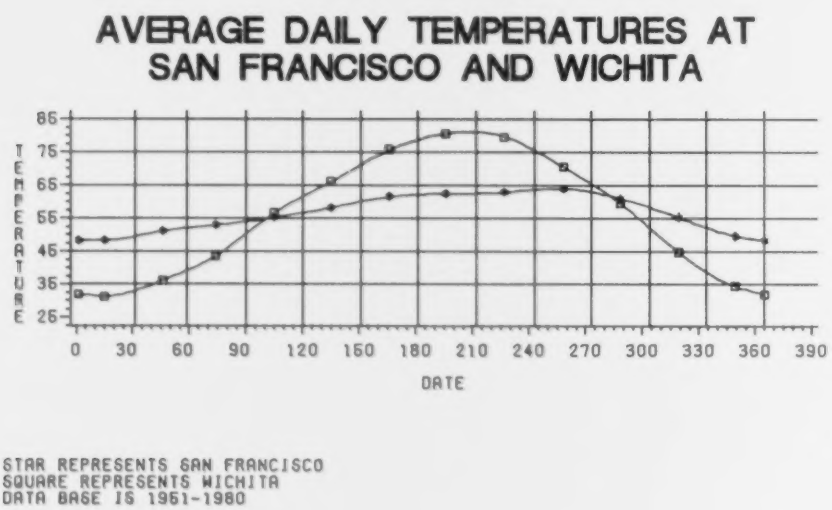


Fig. 1.

UNDERSTANDING D: Mountain ranges can strongly influence local climates.

By blocking and channeling winds, hills and mountains can substantially change the climate of a location. A nearby example is Los Angeles. There, the typical wind direction is from the west (from the Pacific Ocean), and the maximum summertime temperature seldom exceeds 75° F. However, under special circumstances, the wind may blow from the northeast, bringing hot, dry air to Los Angeles and the vicinity from the Mohave Desert. At these times, the temperatures soar to 90° and above, while the relative humidity drops to a few percent. Channeled by valleys that are parallel to the wind, speeds of 100 miles per hour or better have been measured, easily double the average wind speed. Exposed to dry air and winds, vegetation quickly dries out, and brush fires become a real danger.

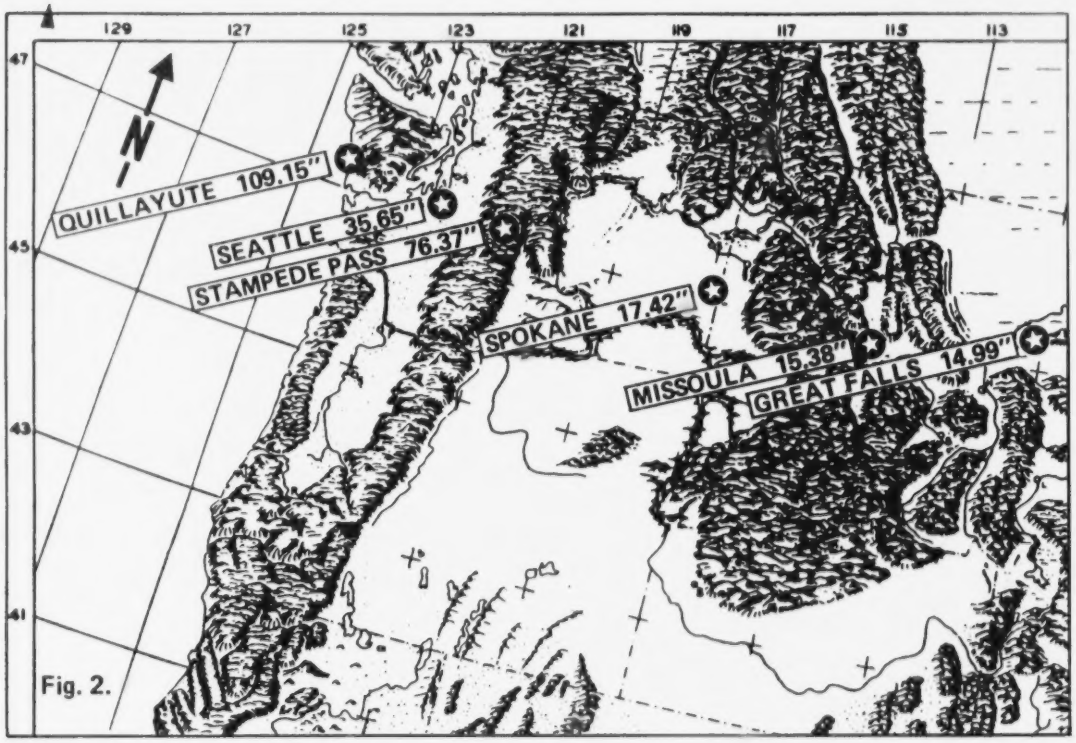


Fig. 2.

Mountain ranges lying across a wind belt also affect the average precipitation. The Olympic and Cascade mountain ranges along the west coast offer an illustration (see Figure 2). Quillayute is located on the extreme northwestern coast of Washington. It has an average annual rainfall of 104.99 inches. The Olympic range lies between Quillayute and Seattle. Seattle has an annual rainfall of 35.65 inches. The Cascade range lies between Seattle and Spokane. Spokane has an average annual rainfall of 17.42 inches. Great Falls, Montana, with an average annual rainfall of 14.99 inches, lies east of the Continental Divide. All of these stations lie in the westerly wind belt. As the moist air from the Pacific Ocean is forced over each range, additional moisture is extracted.

CONCEPT NO. 2: The water cycle is the result of evaporation and precipitation of water vapor.

UNDERSTANDING A: Water vapor enters the atmosphere through the process of evaporation.

Water vapor, the gaseous form of water, is a variable constituent of the atmosphere. It can vary up to about six percent of the atmosphere's volume. Water vapor is added to the atmosphere by evaporation. Sources are open bodies of water, such as the oceans, lakes, rivers and ponds, water in the earth's crust, and transpiration of plants. Minor amounts are added from ices, and the exhalations of animals.

The molecules of any substance are continually vibrating. The higher the temperature of the substance, the faster the vibrations. The molecules attract each other also. When the water molecules are strong enough to keep the molecules "locked" into position relative to each other, an ice crystal is formed.

With the addition of heat, the molecules vibrate faster and collide with one another with increasing force. The increasing motion of the molecules increases the distance between them and the attractive force decreases. The molecules are more free to move around and the water is a liquid. If very forceful collisions of water molecules occur at or near the surface, they can break away and enter the atmosphere as water vapor which is the gaseous form of water.

The process of water molecules escaping into the atmosphere is known as evaporation. Once the water molecules enter the atmosphere, they can be transported by the wind systems to other parts of the globe. It has been estimated that more water crosses the Mississipi River in the atmosphere than flows downstream.

UNDERSTANDING B: Precipitation is the result of water vapor condensing in the atmosphere.

The amount of water vapor that the air can hold is determined by the temperature of the air. The warmer the air, the more moisture it can contain. If the air contains all the moisture it can hold, the air is said to be "saturated".

The actual amount of water vapor in the air can be specified by several methods. Each method has its own advantages and disadvantages. Probably the specification most commonly used is "relative humidity". The relative humidity of the air compares the amount of water vapor actually present in the air to the amount of air it could hold if it were saturated. If a sample of air is warmed without adding moisture, the air can hold more moisture, and therefore the relative humidity decreases. Conversely, if the sample is cooled, the amount of vapor it can hold decreases, and the relative humidity increases.

There are three mechanisms to lift and cool the atmosphere. One mechanism lies in the traveling low pressure systems of the atmosphere. The dynamics of the system require that the air in the system rise. A second method lies in winds blowing against a mountain range. Since the air cannot penetrate the range, it is forced up and over the range. The third method lies in heating the air near the surface of the earth to a point where it is

warmer than its surroundings. Since this air is lighter than its surrounding air, it rises and cools.

Cloud formation is the result of moist air rising and cooling to the point where water vapor condenses into water droplets or ice. When conditions are right, these water droplets are large enough to be pulled to the earth by gravity. This falling of water back to the earth in some form is called precipitation.

An unresolved problem lies in how raindrops become large enough to fall. Cloud droplets are very small; millions of these are required to make one raindrop. There are two theories. Ordinarily, water freezes at 32° F. Water droplets, however, can exist below this temperature. The freezing temperature of a water droplet is determined by its size; the smaller the droplet, the lower is its freezing temperature. Very fine droplets can exist to about -40° F. These very fine droplets can freeze upon contacting a solid. Once ice has formed on a solid, usually a small particle such as dust or salt, it can continue to grow at the expense of water vapor from the water droplets in the cloud. The second theory is the ice crystal can also grow by colliding with other cloud droplets. They finally fall to the ground as raindrops. In the winter when the temperature of the air is below freezing, the precipitation falls as snow.

There is thus a water cycle in the atmosphere. Water evaporates from surface sources and becomes part of the atmosphere. The wind systems carry the water vapor worldwide. Under the proper conditions, the water vapor condenses to precipitation. On the earth's surface, some of the precipitation re-evaporates, some collects in streams and rivers to be delivered to the oceans, while the rest is percolated into the earth. Some precipitation is stored as ice in glaciers, which is eventually returned to the natural cycle.

It is a curious fact that Arizona, which is perceived to be a desert, is a source of atmospheric moisture. A substantial portion of the winter rains which fall on the deserts is stored in the surface soils. With the advent of warmer temperatures in the springtime, the stored water is evaporated into the atmosphere. The water vapor is then, for the most part, carried out of Arizona by the wind systems.

CONCEPT NO. 3: Arizona has many and varied climates.

Within a distance of about 185 miles north and south, the elevation of Arizona soars from about 120 feet at Yuma Valley to over 12,700 feet at Humphrey's Peak. (This vertical

distance encompasses nearly 40% of the total atmospheric mass!) Because temperatures vary with height (see Concept 1.A), a variety of temperature regimes must exist. Air flow over mountains also determines in part the amount of precipitation received (see Concept 1.D). Located between about 31° N and 37° N latitude, the annual amount of possible sunshine varies but little over the state; variable cloudiness, however, does affect actual sunshine receipts. The location of Arizona in two distinct wind regimes (see Concept 1.B) ensures variable amounts of precipitation.

The natural distribution of flora (see sections on plants) requires definite temperature and rainfall regimes. Arizona's many climates thus support a variety of plant life. Soils also reflect the various climates (see Things Geologic). Wildlife, dependent ultimately upon plant life for food, also will be varied in Arizona. (See chapter on Wildlife.) Climate is thus one of the basic determinants of life form distribution in Arizona.

UNDERSTANDING A: Temperatures vary with altitude in Arizona.

In Concept 1.A, attention was drawn to the differences in annual temperatures at Winslow and Yuma. That this change in elevation is not unique to these two locations is shown in Figure 3. Here, the annual average temperatures of about 80 locations in Arizona are plotted against their height above sea level. Clearly, the average annual temperature of a location depends strongly upon its elevation. Since all the points do not lie on a line, it is obvious that while the mean annual temperature depends primarily upon the elevation, other factors are also involved.

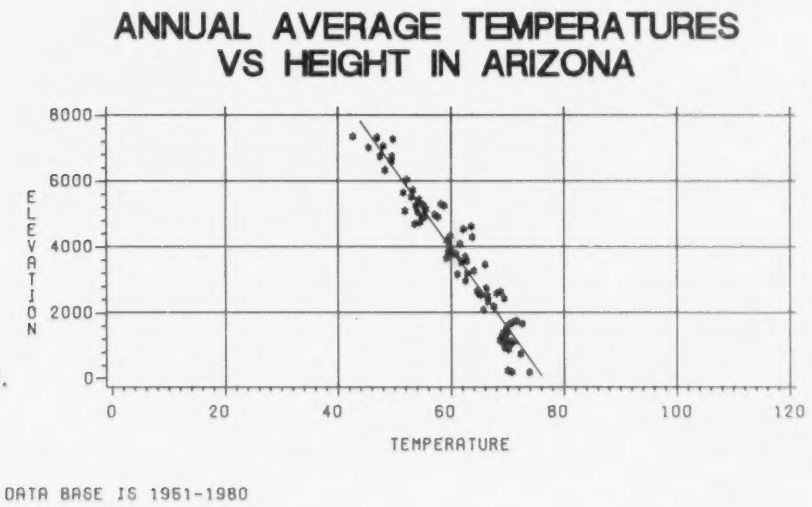


Fig. 3.

Other influencing factors include the topographical location, precipitation and vegetative cover, among other variables. A station located in a valley oriented north-south will miss the early morning and late afternoon solar heating, for example, and so receive less heating than a station located on a plain. Since a moist surface absorbs energy to evaporate water, an area with heavier precipitation will have less energy available for warming the atmosphere. Further, because plants absorb solar energy both for photosynthesis and transpiration, a vegetation-covered surface will be cooler than a barren surface.

Figures 4 and 5 display maxima and minima temperatures plotted against elevation for January and July. Generally, the summer minimum temperatures are about 8.0° F. warmer than the winter maximum temperatures. The average daily annual temperature range is near 35° F. During July, the greatest daily temperature range is at higher elevations. This is because the atmosphere is less dense at higher elevations, so a given amount of heat can cause a larger change of temperature. A secondary reason is that sunshine is more intense at higher altitudes compared to lower elevations. During the winter season, the greatest daily temperture range is at low altitudes. This is presumably due to cold air drainage.

Elevations in Arizona range from near sea level to over 1,000 feet. Average annual temperatures in Arizona, as shown in Figure 3, range from near 75° F. near sea level to about 45° F. at 7,500 feet. At the same rate, temperatures will drop to an average of about -1° F. for a low temperature during January, and soar to about 68° F. for a high temperature during July. Very clearly, elevations in Arizona are a primary determinant of climate.

UNDERSTANDING B: Precipitation varies with altitude and season in Arizona.

Earlier in this chapter, it was pointed out that air must be cooled before condensation of water vapor and precipitation could begin. In nature, large volumes of air are cooled by rising to higher elevations. Two methods are available: the air can either be forced higher by winds blowing against a mountain range such as the Mogollon Rim or against a colder air mass, or by convective clouds, such as cumulonimbi. This assumes that the air contains sufficient moisture to condense for the cooling that is available.

NORMAL MAXIMUM AND MINIMUM TEMPERATURES VS HEIGHT IN ARIZONA DURING JANUARY

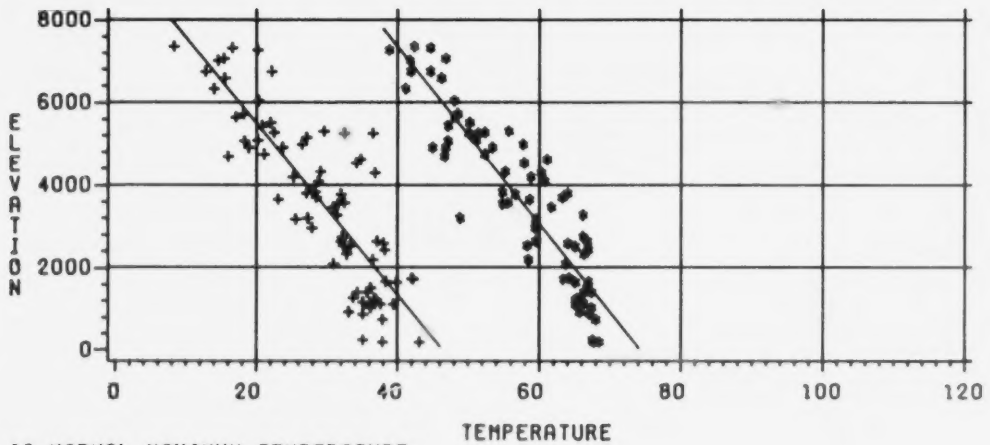


Fig. 4.

■ IS NORMAL MAXIMUM TEMPERATURE
+ IS NORMAL MINIMUM TEMPERATURE
DATA BASE IS 1961-1980

NORMAL MAXIMUM AND MINIMUM TEMPERATURES VS HEIGHT IN ARIZONA DURING JULY

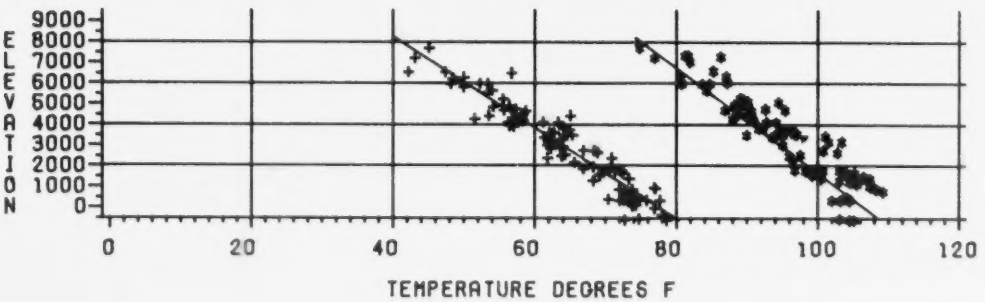


Fig. 5.

■ IS NORMAL MAXIMUM TEMPERATURE
+ IS NORMAL MINIMUM TEMPERATURE
DATA BASE IS 1961-1980

In Figure 6, the annual precipitation amounts for about 114 locations in Arizona are plotted against their altitudes. In the lower desert regions to about 1,500 feet above sea level, precipitation amounts are very strongly dependent upon altitude. Above this level, there is no apparent single trend.

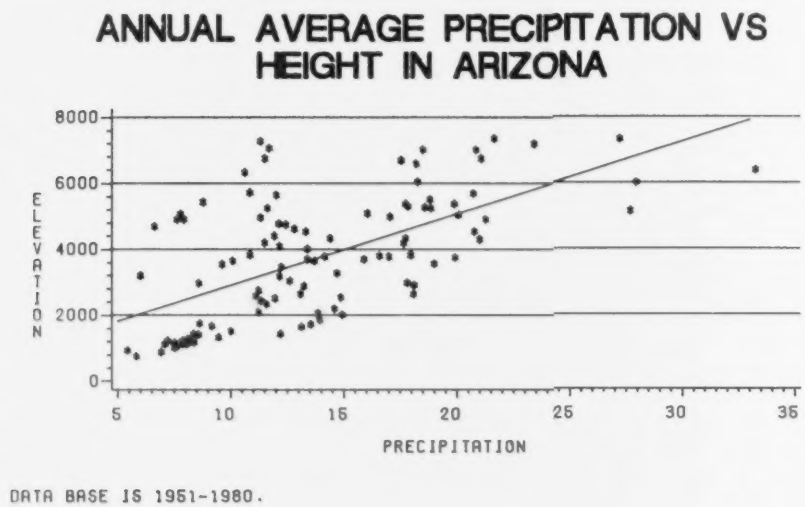


Fig. 6.

Figures 7 and 8 show the normal January and July precipitation amounts for the same 114 stations. While the lower desert stations receive approximately the same amounts of precipitation, the higher altitude stations, those above about 2,500 feet above sea level, show a marked increase. This is particularly true in the 4,000- to 6,000-foot elevation range. Most of these stations are located along the Mogollon Rim and in the eastern mountains.

The dramatic increase of precipitation in this region can be traced to changes in the general circulation of the atmosphere over Arizona. It was noted in Concept 1.B that our state was under the influence of the westerlies during the winter season. Storms originating over the Pacific Ocean sweep across the state, depositing rain or snow. The higher elevation stations receive more moisture than the lower elevation stations because the air is forced to rise and cool -- the mechanism that releases water vapor. The amount of moisture deposited depends not only upon the amount of cooling sustained by the air, but also the water vapor content of the air. If the air over a station has already been dried by a previous lift, less moisture remains to be extracted. Thus, two stations at the same elevation may receive unequal precipitation amounts.

JANUARY PRECIPITATION VS HEIGHT IN ARIZONA

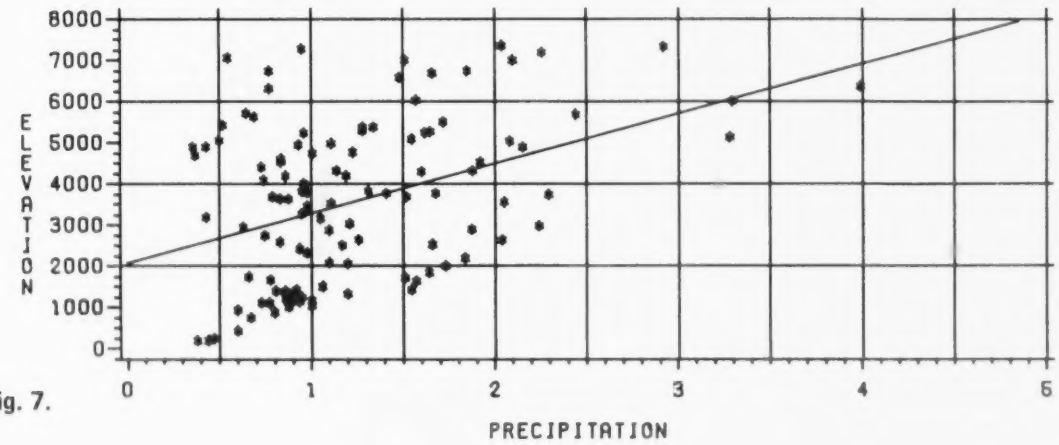


Fig. 7.

DATA BASE IS 1951-1980.

JULY PRECIPITATION VS HEIGHT IN ARIZONA

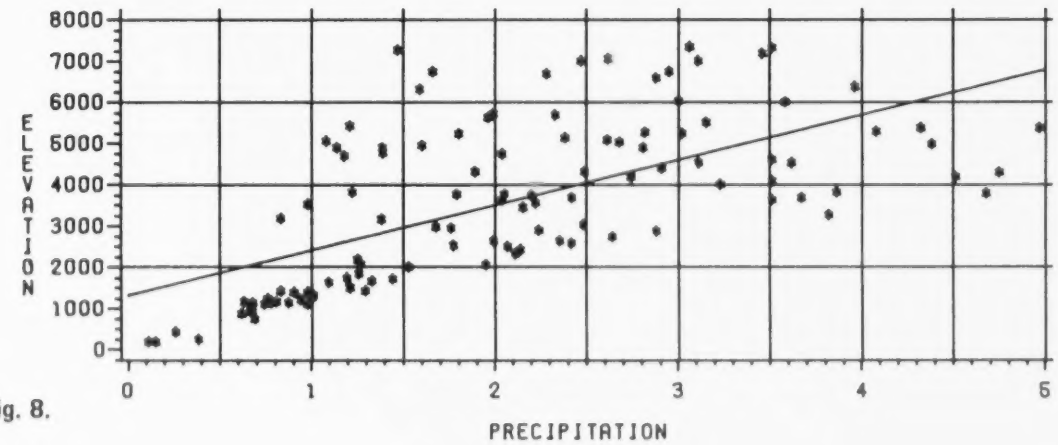


Fig. 8.

DATA BASE IS 1951-1980.

During the summer months, the westerly wind regime is replaced by a southerly air flow. Warm moisture-laden air from the Gulf of Mexico and the southeastern Pacific invade the state at this time, leading to Arizona's "summer monsoon". The lifting necessary for precipitation is now most frequently supplied by the uprush of air in convective clouds, such as towering cumulus and cumulonimbi. The rapid uprush of air releases large quantities of moisture, leading to heavy downpours of rain. These, in turn, may lead to local flooding and disruption of our lives.

UNDERSTANDING C: Arizona has an abundance of sunshine.

Although another state may refer to itself as the "Sunshine State", Arizona may legitimately claim the title. In fact, Yuma has probably the most cloud-free environment in the entire United States. The cloudiness, however, is variable, both in time and place. Cloudiness is related rather closely to the amount of sunshine that is possible, since clouds are very good reflectors of solar energy.

Clouds are masses of water droplets or ice crystals. For them to form, air which contains water vapor must cool to saturation. In the free atmosphere (above the layer next to the ground), the most effective cooling mechanism is through lifting of the air.

As shown by satellite pictures on television weathercasts, generally clouds on any one day do not cover the entire state of Arizona. An example is given in Figure 9, a satellite picture taken at 5 p.m. Mountain Standard Time on April 2, 1985.

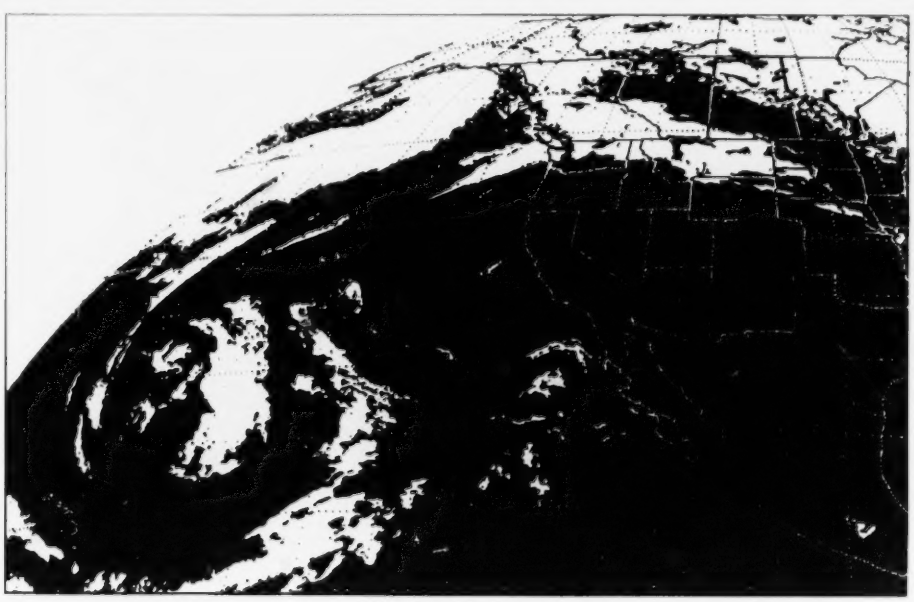


Fig. 9.

WILD RIVER

OBJECTIVES: Participants will be able to 1) understand that there are numerous and sometimes conflicting demands for water and 2) recognize the need and importance of managing and conserving our water supplies.

CONCEPTS AND UNDERSTANDINGS: Water 2C - Water may be used many times. Water 3C - Humans redistribute the surface and subsurface water. Water 5C - Water quality affects usage.

METHOD: Participants will play a simulation game in which the management and use of water is the key issue.

BACKGROUND: The demands for water are numerous. Water is required for drinking and other home uses, for irrigating crops, for fish and wildlife habitat, for navigation, for hydroelectric power, for industry, for recreational purposes, and much more. Yet water is often a limited resource.

Frequently, the water supply is not available where or when it is wanted or the supply is not in sufficient quantity to meet ever growing demands. In addition, existing supplies may be contaminated with chemicals which restrict the use of the water. What happens when the demands for water exceed the amount that is available? Which demands are met? Should efforts be made to increase the water supply or decrease the demands? The answers are not simple.

Efforts can be made to increase the water supply by diverting water from some other place, by storing it, or by pumping it. Usually such actions impact on the environment where these changes are made. An example in Arizona is where excessive groundwater pumping has resulted in ground subsidence and surface cracking.

Many water experts believe that conservation is a better way of ensuring that there is an adequate water supply. For example, considerable savings can be achieved by more efficient irrigation water management, water saving plumbing fixtures, and the repair of leaking water systems.

Many water experts also believe that raising the price of water for agricultural, industrial and domestic use will contribute to reducing demands for water and increasing the amount of conservation of water.

One point all water experts agree upon is that the economic and environmental cost of obtaining clean water is going to increase, and the wise management and proper use of water will be a major environmental challenge of the future.

There are many good examples of water use dilemmas in Arizona that your students could research and discuss. Examples of a few of these include: the Rio Salado project, your community's water use problems, the Bridge Canyon Dam issue, the Central Arizona Project, the Orme Dam issue, the Arizona Groundwater Management Act. As an alternative, you can use a created dilemma such as the following one developed by the National Wildlife Federation for their 1984 National Wildlife Week Packet.

THE WILD RIVER DAM DILEMMA

The Wild River runs through the center of Big Valley County where the city of Bandell and the small town of Olsenville are located.

Bandell, the county seat, has a modest amount of industry and a growing population. Olsenville recently celebrated its two hundredth anniversary and has many historical residences. It is the site of a major archaeological dig of an Indian settlement. The dig is responsible for a steady tourist industry. The Wild River also contributes to the tourist trade. The river is known for its white water rafting, kayaking rapids, and excellent trout fishing. Several small businesses in Olsenville have been built up around these activities.

A 3-mile stretch of river near Olsenville is heavily forested and is a roosting area for bald eagles during the winter. The rest of county land surrounding the river is used for farming. Water is diverted from the river for irrigation.

The Municipal Water District has released a study that states that at current usage rates, the city of Bandell will require additional water supplies and electricity within the next ten years. The Municipal Water Department has suggested a plan to dam the Wild River at Olsenville for water supply storage and hydroelectric power generation.

The dam would store spring flood waters for year-round use and the electricity produced by the power plant could be sold at a low rate to attract more industry to the county. Water would still be available to the farmers to pump for irrigation, but only after the Municipal Water Department has met its customers' needs. A reservoir would be formed by the dam that could be used for boating, swimming, and fishing. However, the six square miles it covered would flood the bald eagle roosting area and the archaeological site. The damming of the river would also eliminate the best stretch of the river for kayaking and rafting.

The County Board of Supervisors must make a decision on whether the dam should be built. The supervisors have scheduled a public meeting to listen to recommendations for and against the project.

The Players and their stands -- 1. The County Supervisors 3 to 5 people
2. Director, Municipal Water District, believes a) Bandell is going to need a more reliable water supply than is now provided by the Wild River in order for there to be economic growth in the region, b) the dam will store excess spring water for year-round use, provide for flood damage reduction, and generate hydroelectric power, c) the new reservoir will provide many recreational activities to replace ones lost by damming the river.
3. Representative, Big Valley Agricultural Association, believes a) large areas of farm land would be flooded meaning 15 families, including his own, would lose their farms, b) with a lower priority for getting water than they now have, farmers could experience crop failure as a result of a moderate drought, c) many farm houses below the planned dam pump water from the river. They would have to drill expensive wells or pay to have water delivered from the reservoir.
4. Director, County Social Services Administration, believes a) construction and new industry will bring in new jobs for the unemployed of the area, b) the taxes received will improve hospital, social services, and fire and police forces, c) county youth recreational programs, facilities, and staff could be expanded because of the increased tax base.

5. President, Wild River Kayaking Outdoor Club, believes a) the low water flow after the reservoir is built would eliminate kayaking down one of the best stretches of white water in the country, b) this area has been proposed as a scenic river area and would be ruined by the dam and reservoir, c) the trout populations above and below the dam would be adversely affected. They would not be able to live in the reservoir because of warmer water temperatures and lack of free-flowing water, d) the building of the dam would disrupt the small businesses in Olsenville and force the owners to close down.
6. President, High Tech Systems Company, believes a) if the dam goes through, the company will relocate to Bandell because of the reasonable electrical rates and desirable community, b) the company will offer 150 new jobs with excellent benefits to the local people, c) High Tech Systems is a relatively nonpolluting industry.
7. Builder, Sunshine Development Company, believes a) increased industry is going to bring more people into the area meaning more housing will be needed, b) the housing boom will create many new construction jobs, c) several restaurants, a sports facility, and a performing arts theater will be built that can be used by all the people of Bandell and Olsenville.
8. Wildlife Management Professor, State College, believes a) the reservoir would flood the winter roosting area for the bald eagles and there is no other suitable area for the eagles wtihin 150 miles, b) there is one wildflower on the endangered species list that can be found only in the area that is to be flooded by the reservoir, c) the forest plain and field area to be covered by the reservoir are excellent habitats for a variety of wildlife that the surrounding agricultural and residential areas could not support.
9. President, Olsenville Historical Society, believes a) reservoir would flood historical sites and completely cover the archaeological site which contains unique artifacts, b) many people who have lived in Olsenville all their lives would have to be relocated, c) the reservoir would change the whole social structure of the town from a quiet village with modest tourist trade to a regional recreation center.

PROCEDURE: 1. Select and research the general conditions of a water situation that affects your community or Arizona.
2. Assign groups of students to different points of view on the situation and have them collect facts and information about the assigned point of view. Have one group of 3 to 5 students be a decision making body.
3. Hold a hearing with one spokesperson for each group presenting the arguments for or against the dilemma.
4. Make a decision.

EXTENSIONS: After a decision is made about the dilemma, follow through on it and then introduce a future impact or change that might occur as a result and have the class solve it.

Invite a representative of your community or county or the local Active Management Area Office of the Department of Water Resources to discuss local water problems and solutions.

Take some action to inform local people about the problems and/or challenge them to take action.

EVALUATION: 1. What is the effect of your promotion campaign?
2. Write a research paper on the history of water rights in Arizona.

Grades:	7-12
Subjects:	Language, Reading, Arizona History, Civics
Skills:	Analysis, Application, Description, Discussion, Evaluation, Generalization, Problem Solving, Research, Small Group Work, Writing.
Group Size:	24 or more
Key Vocabulary:	

WET DIRT

OBJECTIVES: Participants will be able to: 1) describe the important relationship between soil and water, 2) illustrate how soil texture affects water-holding capacity of soil, 3) understand how water is polluted as it moves through soil.

CONCEPTS AND UNDERSTANDINGS: Water 4B - Water performs many physical functions. Water 4C - Water performs chemical functions. Water 5A - Water picks up natural and human-made substances as it moves over and through the earth. Soil 1C - Climatic factors affect the formation of soils. Soil 3A - Soil texture determines many of a soil's characteristics. Soil 4A - Soil regulates water movement and is a cleanser of water. Soil 5A - Accelerated erosion by wind or water causes increased soil loss.

METHOD: Water will be both dropped and poured onto soil to show the relationships that exist between these two resources. This activity can be conducted as either a demonstration or a hands-on experience.

BACKGROUND: Rocks and soil provide the medium in which plant seeds normally germinate and into which the roots grow and find nourishment. However, without water or with limited amounts of water, the rocks and soil have limited potential to support plant growth. In Arizona, where we often irrigate to produce large amounts of plant material, understanding the relationship between these basic resources and the differences within the rocks and soil allows us to manage them better.

MATERIALS: Three (3) or more transparent or translucent, plastic tubes similar to those used in golf bags to protect the golf club handles (found in a sporting goods store); samples of 3 or more soils (the soils should be pulverized or sieved so that few, if any, clumps of soil remain), and some different size gravels (a couple of one-pound coffee cans full is enough of the soil and one can full of gravel); 15 paper plates, water source, eye or nose dropper, several paper cups, rubber bands, small pieces of old sheet.

PROCEDURE: 1. Divide the class into one group for each different sample of soil or gravel that you have available. Give them a handful of one of the samples and a small amount of water in a paper cup and ask them to describe what they have. With the soil samples, they can describe it better if they dampen it with a little water and work it in the same manner you might work modeling clay.

2. Place a small amount (two or three tablespoons) of each soil or rock material on a separate plate and drop water onto it from the eye dropper. By placing a large piece of white paper under the plate, or putting the sample in the middle of the paper, the students will be able to see the results better. What happens as the water strikes the surface? Continue this process long enough to show the drops of water and soil splashing out onto the paper away from the sample. What would happen if this had been a raindrop? Why did some materials move and not others?

3. Put a piece of cloth over one end of each tube and hold it with a rubber band. Fill the tubes about three-fourths full of the different soil and rock materials; a different sample in each tube. Ask the students, which of the materials will hold the most water? Pour an equal amount of water into each tube and place a cup below the tube to catch any water that comes through. Although the students might hold the tubes while you are doing this, it might be better to have some kind of stand to hold them, because it will take several hours for the water to move through the fine textured soils. When all the water has entered the soil or rocks and moved as far into or through the sample as it can, measure the amount of water collected in the cups and compare them. Why did one sample hold more water than another? In which sample did the water move through the fastest? Which soil will hold the most water for plant roots?

4. Get enough more soil to fill one of the tubes. Fill the tube about three-quarters full of soil and then pour off the top third of soil into a can. Mix two or three tablespoonsful of green or red jello into this soil and then pour it back into the tube. Now pour enough water into the tube, either all at once or by adding a little bit at a time, until the water comes out the bottom. Compare the color of the water you added at the top to the color of that which came out the bottom. Discuss with the students how water in soil does the same thing with plant nutrients. Ask, what happens to the plant nutrients if irrigation water is applied too heavily and goes below the root zone of the crop, or if water percolates through a landfill where poisonous chemicals have been dumped and finally reaches the groundwater?

EXTENSIONS: 1. Grow a bean in one or more of the tubes and in one or more soil types and keep track of the irrigation water that is added. If you use the same soil type in several tubes, vary the amount and frequency of irrigations.
2. Fill three tubes with 24 inches of different types of soil and then place the covered end of the tubes into a jar or cup of water. Use stands to hold the tubes and observe the water moving up in the soil over at least a 24-hour period.
3. Fill three tubes with enough of a clay or clay loam soil so that water will move up through the soil to the surface and put them in water as in extension 2. However, instead of using just tap water, use tap water for one tube and different concentrations of salty water for the other two. After a week or more, you should be able to see a salt crust beginning to form on the surface of the soils in salt water. Be sure to maintain sufficient water in the supply cups so that water continues to move up through the soil profile. Discuss with your students how, in areas where high water tables occur, this same process contributes to soil salinity and ask if in irrigated areas using salty water this might eventually reduce the crop production in an area.
4. Measure and keep track of how much water is used to irrigate an area on your schoolgrounds. Is this too much or too little? The local Soil Conservation Service or County Extension Agent can probably tell you how much water is needed to adequately maintain the grass used on your grounds.
5. Fill a couple of tubes, one with small gravel and one with soil, and pour dirty water into the tops. Continue to add dirty water until water comes out the bottom. Was the water still dirty when it came out the bottom? Now try this same thing, but pour salty water into the soil. Was the water still salty when it came out the bottom? Why the difference?

EVALUATION: Write an essay or draw a chart or mural that shows how soil and water relate. Show in a drawing or chart how soil texture affects water-holding catacity. Write an essay on how a home gardener or farmer can use this information about soil and water to conserve both his water and his soil.

Grades:	K to 12
Subjects:	Science, Language, Health, Visual Arts
Skills:	Anaysis, Application, Classification, Comparing Similarities and Differences, Description, Discussion, Drawing, Evaluation, Experimenting, Generalization, Making Inferences, Observation, Problem Solving, Small Group Work, Writing
Group Size:	15 to 25 younger students; depends on amount of equipment with older students.
Key Vocabulary:	texture, percolation, infiltration, absorb, adsorb, capillary, clay, silt, sand

TERRARIUM TRANSPIRATION

OBJECTIVES: Participants will be able to: 1) observe the water cycle and 2) relate the small scale model to the larger regional and worldwide water cycle.

CONCEPTS AND UNDERSTANDING: Water 1B - Water occurs in three physical forms. Water 2A - Water is distributed and renewed through a water cycle. Water 2B - Water plays an important role in other cycles and processes. Water 2C - Water may be used many times. Water 4A - Living cells depend upon water.

METHOD: A miniature hydrological cycle will be created for the classroom in the form of a terrarium.

BACKGROUND: The water or hydrological cycle is one of the largest physical processes on Earth. It is important for all of us, especially young people, to understand this cycle and the role it plays in the lives of all living things. When presenting this activity it would be helpful to have a diagram of the water cycle. The complexity of this diagram would depend on the age of your students.

MATERIALS: A large glass jar with a wide mouth or an aquarium that can be sealed tightly, gravel, sphagnum, soil, violets or moss, water source.

PROCEDURE: 1. In the bottom of the jar or aquarium, place a one-inch layer of gravel. Cover the gravel with about one inch of sphagnum and then add an inch or two of soil.
2. Plant the violets, ferns or moss in the soil. Other small plants would also work.
3. Water the terrarium lightly and then seal it.
4. Observe water collected on the top of the terrarium, especially in the morning as a result of transpiration. Then watch it "rain" back onto the soil and plants.
5. After observing this cycle for several days, discuss the water cycle which is occurring and relate it to the larger cycle on a regional, state, national and international basis. Use the diagram of the water cycle.
6. If the material is available, allow the students to create their own terrarium on a small scale.

EXTENSIONS: 1. Try this same activity, but leave out the plants, add a little more water, and place the terrarium in the hot sun. Carefully observe this early in the morning and again in the afternoon.
2. Tie a medium-size plastic bag over one or two leaves of a tree or shrub, or on a conifer over the last three to five inches of a branch. Do this the first thing in the morning and then collect the bag just before school is out. Measure the amount of water collected by weighing the bag before and after it has been tied to the branch or by pouring the water into a measuring cup.

EVALUATION: Draw the water cycle and label the key parts of it. Have older students compute the amount of energy required to lift the water transpired by a large tree in one day or a week. Calculate the amount of energy that impacts on one acre when an inch of rain falls on it. Write an essay or poetry to describe the water cycle. Trace the route of a drop of water through the water cycle. Write and act out a play that tells the story of a drop of water going through the water cycle.

Grades: K-12

Subjects: Science, Visual Arts, Language

Skills: Analysis, Application, Computation, Description, Drawing, Evaluation, Generalization, Observation, Writing, Experimenting.

Group Size: 10 to 30

Key Vocabulary: evaporation, transpiration, condensation, precipitation, terrarium

WHERE'S THE WATER

OBJECTIVES: Participants will be able to: 1) visualize the different places where water is found, and 2) discuss the different forms in which it is found.

CONCEPTS AND UNDERSTANDINGS: Water 1 - Water is a naturally occurring compound.

METHOD: Participants will read about and list the places where water is found and the form in which it is found.

BACKGROUND: This activity will set a basis for the other activities in the Water Chapter, as well as helping the students to specifically prepare for Concepts 1A, 2A, 3A, and 3B.

MATERIALS: Reference books on water, paper, and pencils.

PROCEDURE: Have students research, or discuss with them in class, where water is found and whether it is found as ice, liquid, or gas. Have them list these items, or draw pictures to illustrate them.

EVALUATION: Primary evaluation of this activity will occur as the students work on other activities in the Water Chapter.

Grades:	K to 3
Subjects:	Language, Reading, Visual Art, Spelling, Geography
Skills:	Description, Discussion, Evaluation, Research
Group Size:	Any
Key Vocabulary:	Liquid, Gas

WATER MAGIC

OBJECTIVES: Participants will be able to: 1) observe water in two of its physical forms, 2) theorize what happens in the evaporation process, and 3) observe residues left after water evaporates.

CONCEPTS AND UNDERSTANDINGS: Water 1B - Water occurs in three physical forms. Water 5A - Water picks up natural and human-made substances as it moves over and through the earth.

METHOD: Participants will touch and measure water in both the solid and liquid physical forms and observe how these forms act when exposed in the classroom.

BACKGROUND: Information is found in the Water Chapter.

MATERIALS: Refrigerator, small plastic glasses or a jar, water source, rulers, balance scale, tea kettle, electric hot plate, and mirror.

PROCEDURE: 1. Show the students an ice cube, or provide each student with a cube and a clear plastic glass.
2. Ask the students what the cube is made of and ask them to put them in the glass and observe what happens.
3. When the ice has melted, discuss the difference between the solid form of water and the liquid form.
4. Have the students leave their glasses of water on a shelf and ask them what they think might happen.
5. When the water has evaporated, discuss with them what has happened and compare this to their answers to what they thought would happen in step 4.
6. Observe the sides and bottom of the glasses and, if necessary, compare them to a new glass.
7. Discuss with them where the film came from that is left on the sides and bottom of the glass.
8. Heat water in the tea kettle and, when boiling, hold the mirror over the opening in the spout and observe what happens.
9. Discuss with them how water becomes steam and is able to move into the air. (This can be tied into the water cycle in Concept 2A.)

EXTENSIONS: 1. Fill one of the plastic glasses about two-thirds full of water and measure the depth of the water and weigh the glass and water. Then freeze them and, when frozen, measure the depth and weigh the glass and ice. Compare the differences, but measure carefully.
2. After step 7 in the procedure, have them wash the glass and see if they can get it as clean as the new glass. Discuss with them what happened to the film on the glass and how the water was able to pick up the materials.
3. Discuss how water moving through the soil or rocks is able to pick up either natural or man-made substances. This could be shown by placing some soil mixed with a green or red jello in a container with two open ends and pouring water through it.

EVALUATION: Have the students describe the three physical forms of water and compare them. They could also draw the things they have observed.

Grades:	K to 4
Subjects:	Science, Arithmetic, Language, Health
Skills:	Analysis, Comparing Similarities and Differences, Discussion, Drawings, Evaluation, Experimenting, Observation
Group Size:	Any
Key Vocabulary:	Solid, Liquid, Gas, Vapor, Absorb, Evaporation

ARIZONA'S GEOLOGIC TREASURY

This activity is divided into three parts:

1. Making a Mineral Resource Map
2. Analyzing the Map
3. You and the Treasury

OBJECTIVES: To learn something about Arizona's geologic resources by: 1. making and interpreting a map; 2. noting resource types, diversity, and uneven distribution; and 3. discussing each individual's role in the consumption of geologic raw material resources, and to discuss resource diversity as a function of diversity of geologic habitats (obvious analogy with wildlife and habitat diversities).

CONCEPTS AND UNDERSTANDINGS: Things geologic: 1(c) Geologic things are a fundmental part of the life support system that makes all living things, including people and their civilizations, possible.
2b. No two places on earth are geologically identical.
2c. There is only one "crop" of most geologic resources (minerals, fuels).
3. Earth materials "grow" in, and are products of, contrasting geologic environments.
4. Although humans live at the earth's surface, they have become dependent in large measure upon depletable geologic resources beneath it (the geologic treasury).

PART I
Making a Mineral Resource Map

OBJECTIVES: To make a map of some useful geologic materials produced in Arizona.

METHOD: Under teacher guidance students make a map of some of the earth materials extracted from Arizona. Teacher asks questions and leads a discussion.

BACKGROUND: Modern developed societies make use of a large variety of geologic materials. Some of these are obtained locally and others are imported, often from foreign countries. Every region has its own set of materials, assets and liabilities that shift with time as new demands and new information accumulates. Continuing geologic investigations are essential in order to inventory what is, and might be, in the earth's treasury from place to place. No two places are geologically identical, therefore, it takes ongoing systematic observation and study to define what the earth is really like. From such studies we've learned that Arizona, for instance, has an unusual treasury of copper deposits. For many years over 60 percent of the copper mined in the U.S. came from Arizona. Because of this, Arizona has been very important to the nation as a supplier of copper. Why should just a portion of one state out of 50 contain so much copper? Why does Saudi Arabia have so much oil? While we know that the reasons are geological, it is very difficult to pin down the final why's. Just because we can't always explain such phenomena does not lessen the impact of the fact that it is so. Unequal distribution of resources is a fact of life which must be confronted. The earth is as it is, and we must deal with it accordingly. The first trick, however, is to learn how it is! The accompanying map-plotting exercise will be followed up with some analysis that considers resource distribution patterns within the state.

The value of Arizona's nonfuel rock and mineral resources produced in 1981 was 2.56 billion dollars, 76 percent (1.95 billion dollars) of which is attributed to copper alone. Combined metals, including copper, molybdenum, silver, gold, lead, and zinc, accounted for 92.5 percent (2.37 billion dollars), whereas the nonfuel nonmetallic rock and mineral products accounted for just under 8 percent (197.5 million dollars) of the total nonfuel production. Estimated fuel production value was 10 million dollars for petroleum and 150 million dollars for coal, for a total of 160 million dollars.

Estimated Value of Earth Materials Production in Arizona - 1981
Metallics-Nonmetallics-Fuels

Commodity	Value ($)	% of	Total
Metallics	$2,368,383,000		87.0%
Copper	1,953,142,000	71.7	
All Others	415,241,000	15.3	
Nonmetallics	197,457,000		7.2
SUBTOTALS	$2,565,840,000		94.2
Fuels	160,000,000		5.8
Petroleum	10,000,000	.4	
Coal	150,000,000	5.4	
TOTALS	$2,725,840,000		100.0

Ranking in U.S. in Value of Nonfuel Mineral Production - 1981
(U.S. Total = $25,173,000,000)

State	Value	Rank	% of U.S. Total
Arizona	$2,565,840,000	1	10.19
Minnesota	2,151,871,000	2	8.55
California	1,975,016,000	3	7.85
Florida	1,725,589,000	4	6.85
Texas	1,658,203,000	5	6.59

Another way of evaluating the significance of copper resources in Arizona is to compare copper production in Arizona with that of the rest of the world. In 1981, Arizona (just one state in the United States) gave up more copper than any country in the entire world, except Chile, which barely nosed us out. Yes, copper production in Arizona even nosed out Russia! Utah and New Mexico are second and third respectively, to Arizona in U.S. production of copper. This disparity, however, is so large that the copper production from even single Arizona county, such as Pima or Pinal, was more than the total from any other state, and most countries. Ten of the fifteen largest copper mines in the U.S. are in Arizona.

Based upon this criteria, it is fair to state that copper in Arizona is a unique planetary resource and is an example of the inequality in resource distribution within the earth's crust.

About 11 tons per person of nonmetallic materials (stones, sand, gravel, salt, clays, cement, lime, etc.) is produced each year in Arizona.

MATERIALS: One copy of map and data sheet for each student. Pencils.

PROCEDURE: 1. Hand out one set of data sheets to each student.
2. Instruct them as to what they have. They have: (a) a map of Arizona showing counties, and (b) a sheet giving certain geologic materials, symbols, and locations in terms of a letter and a number.
3. Note the letter/number grid on the map and ask them to plot each commodity in its appropriate location using a commodity symbol. (You can develop your own symbols, even a color key - as long as all agree on a standard symbology.) Be sure to number each map location with the number shown on the data sheet.

PART II
Interpreting Map

OBJECTIVE: To interpret the resources map completed in Part I.

METHOD: Under teacher guidance, students interpret the map.

MATERIALS: Copy of map made in Part 1, paper and pencil, and a list of questions (optional).

PROCEDURE: Teacher can hand out questions, write them on the board, or ask them orally. It depends upon the amount of guidance required by the age group.

Sample Questions:

a. How many counties are there in Arizona? (15)
b. How many copper mines are shown?
c. How many counties have copper mines?
d. What province (region) are the copper mines in?
e. Are there any copper mines in the Plateau region?
f. In which region are the energy materials (coal/uranium/petroleum) being produced?
g. Which region is the copper province?
h. Which region is the energy province?
i. How many cement plants are there?
j. In which two Arizona cities would most of the cement be used?
k. Which county has a productive zeolite deposit?
l. Is there a lot of information on the map you made in Part I?

PART III
People - You! - and the Geologic Treasury

Note: Teacher should review the introduction to the activity.

OBJECTIVE: To discuss the activity and draw final conclusions.

METHOD: Teacher-led discussion.

MATERIALS: Chalkboard, chalk, information from Parts I and II.

PROCEDURE: Stimulate discussion by asking questions which promote a conclusion (see Part II):

a. How do you make use of earth materials?
   Identify material things in the classroom that are made from rocks or minerals, e.g., metallic objects (made of metal) or nonmetallic things (glass, ceramic, stone, cement, plaster, chalk, jewelry, etc.). Consider one day in their lives: what "geologic" materials, or things made from geologic materials, do they use or encounter? Consider energy, transportation, housing, tools and appliances, etc. - make a list. Where do they all begin? In the earth!

b. How would life be different if we didn't take rocks, minerals, and energy materials from the earth?

c. See the map of Arizona and call everything on the Colorado Plateau "Northern" Arizona and everything in the Basin and Range Country "Southern" Arizona. Ask the following question: In which part of the state (north or south) would you go to find Coal/Copper/Zeolite/Gypsum?

d. How do you explain the fact that coal and copper are not found in the same part of the state?
   What controls where useful earth resources occur? A geologic history that varies from place to place. Rocks and minerals are products of geologic environments and these environments changed in both space and time.

e. Discuss habitat. What is it? It is a place where a thing naturally exists? Are the habitats of elk and trout the same? How about the habitats of petroleum and copper deposits? To predict where things are, we need to know their association. This is true for minerals, plants, and animals.

f. In what important ways are grain, timber, and deer different than copper, coal, and oil? One group is renewable and the other is not. There is only one "crop" of most rocks, minerals, and coal-petroleum.

g. Is what's under the ground important? Why?

h. Should we be studying the earth to learn more about its natural treasury of useful (essential) materials? In Arizona, too?

EXTENSIONS: Numerous opportunities exist to write an essay on the importance of what we can't see beneath the earth's surface; draw cartoon, etc. showing connections between earth resources and material things, e.g. as a minimum should include the earth (mine, well, quarry), processing plants, manufacturing plant, and the final item. Review some of the environmental trade-off effects associated with providing people with products made from earth materials. Consider information gathering through letter writing, field trips, speakers, etc.

EVALUATION: Discuss implications for the future:

a. Increasing populations and rising expectations.

b. A fixed supply of important earth materials.

c. How to function when we cannot know everything that we'd like to know about resource quantities in the earth's treasury.

d. The need for continued research and the importance of conservation (by whom?).

e. Nobody ever said it would be easy!

f. Is the future guaranteed?

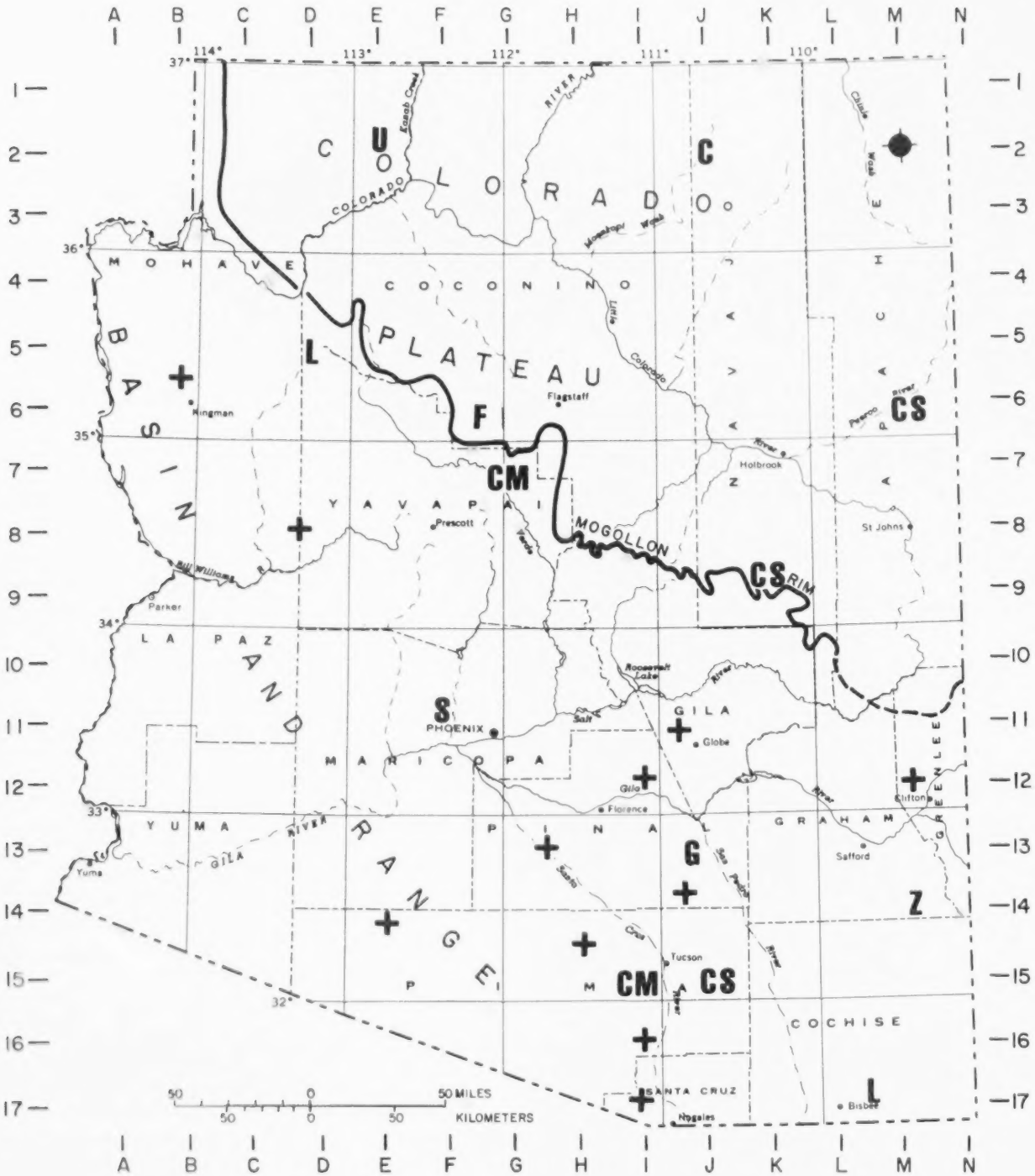
g. Is the earth in charge?

Grades:	5-12
Subjects:	Science, Social Studies, Reading
Skills:	Analysis, Application, Comparing Similarities and Differences, Computation, Discussion, Generalizations, Making Inferences, Mapping
Group Size:	Any
Key Vocabulary:	Basin and Range, Province, Depletable, Geologic Habitat, Plateau Province

SOME EARTH MATERIALS PRODUCED IN ARIZONA

TABLE 1

ENERGY MATERIALS	SYMBOL	LOCATION
1. Crude oil - Largest oil field	●	M-2
2. Coal - Large mines (2)	C	J-2
3. Uranium ore - Currently active mine	U	E-2
NONMETALLIC MATERIALS		
4. Lime (from Limestone)	L	D-5, L,M-17
5. Flagstone	F	FG-6
6. Clays-shales	CS	M-6, K-9, J-15
7. Cement (from Limestone, etc.)	CM	G-7, I-15
8. Salt	S	F-11
9. Gypsum	G	J-13
10. Zeolite	Z	M-14
METALLIC MATERIALS		
(Some Major Copper Mines)	+	
11. Ithaca Peak		B-5,6
12. Bagdad		D-8
13. Pinto Valley		I,J-11
14. Ray		I-12
15. Morenci		M-12
16. San Manuel		I,J-13,14
17. Ajo		E-14
18. Casa Grande		G,H-13
19. Silver Bell		H-14,15
20. Pima - Mission		I-15,16
21. Twin Buttes		I-16
22. Esperanza		I-16,17



MAP OF ARIZONA WITH LOCATIONAL GRID FOR PLOTTING COMMODITIES LISTED IN TABLE 1.

HIDDEN WATERS UNDER THE DESERT

OBJECTIVES: To learn that vital water resources are naturally stored underground (ground water) in geologic materials. To demonstrate the water storage capacity of loose geologic materials.

CONCEPTS AND UNDERSTANDING: 1(c) Things geologic are a fundamental part of the life-support system that make all living things, including people and their civilizations, possible. 4(a) Although humans live at the earth's surface, they have become dependent in large measure upon depletable geologic resources beneath it. Discovery is required before new resources can be developed and utilized. 5(d) A dilemma - no one can really know what the ultimate in practical earth-materials supply is. We can do no better than to become aware and then to provide better training and facilities for the best brains that can be found.

METHOD: Demonstration by teacher, student and teacher record data, students predict results, discussion.

BACKGROUND: For many years, nearly two-thirds (66%) of Arizona's water supply has been withdrawn from natural underground groundwater-storage reservoirs (aquifers). Ninety seven (97%) of this is pumped from less than half the area of Arizona. How come the other half of the state gives up only 3% of the groundwater? It's all in things geologic! It's the same reason that over 93% of the population, over 93% of the agriculture, and over 93% of the value of mineral production is in southern Arizona.

From the point of view of groundwater reservoirs, or aquifers, northern Arizona's plateau region is deficient in high capacity subsurface storage potential. The rocks are relatively old, hard, with minor pore space.

Southern Arizona, on the other hand, is the basin and range region, where valleys are filled with relatively young and loose gravel, sand, and silty sediments having abundant pore space. Excellent soils (geologic materials) in the valleys, along with abundant groundwater, support an agricultural industry.

Large quantities of water are measured in acre-feet (an area of one acre covered by one foot of water - a regulation football field is one-acre in size). It is estimated that over five (5) million acre-feet of groundwater was pumped from Arizona in 1981. How much water is this? Make an aquarium the size of a football field and extend its sides five (5) million feet into the air (over 950 miles required to contain this production). All but 3% of this came from beneath Arizona's desert regions!

MATERIALS: One large translucent plastic container (preferred) or coffee can if that is available, enough dry sand or sandy gravel to fill container, kitchen tool to measure liquid volume either in cups or fluid ounces, source of water, and pencil, paper or blackboard for recording data.

PROCEDURE: 1. Establish the capacity (volume) of the container by filling it with water from a measuring device. Record this figure as volume of container.
2. Empty the water and refill the container with the sandy material. Fill to just below the top and do not pack it down.

3. Consider what's not in the container. In addition to the material added, there is air in the voids or pore spaces between particles. The volume established in step (1) is now occupied by loose material and air.
4. Ask students to estimate how much water the sand-filled container will hold (use cups, ounces, etc.). Have them write down their estimates.
5. Slowly pour water from a measuring device into the sand until container almost overflows. Note volume poured and record the number. What is this number? It is the volume of pore space between particles that was filled with air. At this point the volume of the container is occupied by both sand and water.
6. By a show of hands, determine whether the majority overestimated or underestimated the amount of water the sand-filled container would hold.
7. Summarize by making a table as follows:

a. Volume of container (see proc. 1) _____ measured _____

b. Volume of sand plus air (see proc. 3) _____ same as (a) above _____

c. Volume of water added to sand (see proc. 5) _____ measured _____

d. Volume of sand itself is equal to the total volume of the container minus the water added to the sand. _____ a - c _____

e. What fraction or percentage of the sand-filled container was pore space?

_____ c/a or c/a x 100 = % _____

Expressed as percentage this parameter is porosity.

8. Review concepts, understandings, and objectives. How does water get underground? Some surface water flow seeps beneath the surface, especially where the rivers and washes flow. This is called recharge. Is this a good place to store large amount of water? Why? No evaporation, lots of space, water not contaminated by bacteria because of lack of oxygen and sunlight, etc. How long has this storage of groundwater been going on? For as long as conditions have existed. When water storage capacity is filled, surface streams become more active. Think of southern Arizona valley as a bathtub filled with sand. How old is underground water? Much of it is thousands of years old. Why doesn't it spoil? No oxygen - no bugs!

EXTENSIONS: Opportunities to explore many aspects of groundwater in Arizona, etc. How is groundwater used? Most of it (83%) is utilized by agriculture. How fast is water being pumped from underground? In many places faster than it is being recharged (four times faster is the Tucson area!) This is called "mining" water. How might underground water become contaminated? Where does your town obtain its water? Find out! Are there any problems in using large amounts of groundwater? Severe subsidence of the land surface because of groundwater withdrawal is a known fact in several places in Arizona. In the last 40 years the whole town of Eloy has subsided at least seven (7) feet! Subsidence has recently been detected in Tucson. This is a growing threat to many southern Arizona communities. Why subsidence? The water is a part of the geologic foundation that provides support for what is above it. Removing water allows the dewatered materials to compact. Upon reaching the surface this process causes subsidence and severe cracking at margins of subsidence. As the underground water is lowered because of pumping, what happens to costs? They rise? Why?

EVALUATION: Compare and explain the differences between how early Indians obtained water and how we do it today in southern Arizona. Where is most of Arizona's water stored? Are there vital geologic resources that occur where they cannot be seen? Discuss why there is abundant good water beneath the earth's surface in southern Arizona desert valleys.

CONCLUSIONS: 1. Water that has been naturally stored underground for thousands of years is vital to Arizona.
2. Underground water (groundwater) is being pumped faster than it is being replenished.
3. This basic resource is controlled by a geologic setting that cannot be seen directly- it is out of sight.
4. We must understand this resource if we are to make maximum efficient use of it. "Understanding" it requires trained personnel and the expenditure of money.
5. In a desert the closet water is usually down under our feet - the home of hidden waters.
6. Pumping large amounts of groundwater from a basin usually leads to surface land subsidence and earth cracking along basin margins. This is an environmental consequence that will become an increasing cause for concern.

Grades:	6-12
Subjects:	Science
Skills:	Analysis, Charting, Computation, Experimenting, Making Inferences, Measuring, Observation, Reporting
Group size:	Any
Key vocabulary:	Groundwater, pore space, recharge.

DON'T KNOCK THE ROCK

OBJECTIVES: To show: 1) that nonliving factors (rocks and minerals are emphasized in the activity) contribute basic essentials for the support of all life, and 2) that the order of appearance on earth was Mineral (things Geologic), Vegetable, and then Animal.

CONCEPTS AND UNDERSTANDING: 1(a) Because the requirements for life support necessarily precede life, and plants are the bridge to animals; it logically follows that the order of appearance on earth of the three general kingdoms of matter was: (1) MINERAL, (2) VEGETABLE, (3) ANIMAL.

METHOD: Teacher-led discussions; development of ecological principles through inductive reasoning; application of principles established.

BACKGROUND: The earth was differentiated into land, sea, and atmosphere prior to the development of life on earth. Thus, the earth's basic constituents are nonliving solids (rocks and minerals), liquid (water), and gases (atmosphere), each of which is a vital component of the overall life-support system. The sun, rocks, minerals, air, and water are like links in a chain - each is important to the function of the whole because a total failure of any one factor would lead to the failure of all life. Most of us are quite aware of the essential role of sun, air, and water in our lives. How about the basic solids, rocks and minerals, that make up land? How do they figure in the life support system? Understanding the vital role of rocks and minerals and their contents, in supporting life on earth, is made difficult by a measure of indirectness - the matter is not simply intuitive to most people - it is more intellectual. Do rocks and minerals need people? Does life need rocks and minerals? Let us count the ways!

"Mineral", as a Mineral Kingdom, has to be a term that catches every substance that is not animal and/or vegetable. In this sense, air and water are "mineral". In the expression "rocks and minerals", however, mineral is limited to its more restricted, more formal meaning that embraces the diverse species of solid compounds that combine in various ways to form rocks.

What does the Vegetable Kingdom "eat"? With but few exceptions, it relies directly on substances that are nonliving, the so-called plant foods contained in minerals, air, and water. "Soil" is a thin part of the solid earth that irregularly occurs at the earth's surface as a result of geologic processes. It consists largely of mineral particles derived from rocks. Soils vary greatly in type, origin, distribution, and thickness. They tend to be loose and spongy and therefore susceptible to cultivation and the infiltration of water and air. Many mountain ranges consist of hard rock that cannot be plowed, yet support large forests. Why? Most rocks are fractured, which allows small particles of rock debris to collect, seeds to gather, water to infiltrate, and roots to penetrate. Roots in contact with hard rocks can extract "food" from the minerals just as they do from minerals in soils derived from the weathering of rock.

The Vegetable Kingdom is the food bridge between the nonliving rocks and minerals, and animals. Do animals eat rocks and minerals for nourishment? Only indirectly through plants. No rocks and minerals, no plants. No plants, no animals. No rocks and minerals, no animals, and no you!

MATERIALS: Teacher: Blackboard and chalk (or substitute), a potted plant if available. Students: Paper, cards, or tagboard cut to size (3 per student), pencils or crayons.

PROCEDURES: 1. Make it clear that the object of this exercise is to investigate the very basics of how the earth supports life.

2. Ask students what their most basic needs are to stay alive and to rank them in order of importance (what would cause them to die first, etc.). Make a list of ideas on blackboard until a consensus is reached that there are three vital items: Air, Water, and Food.
3. Ask what their two main sources of food are: plants and animals (not the supermarket). Erase food from procedure 2 and replace with plants and animals.
4. Explore basic animal needs and determine if any items should be added to the list in procedure 2 (should not be necessary to add any).
5. Now explore plant needs. Do plants need "food"? Where do they get it? We know that plants need water, carbon dioxide and nitrogen. In addition, they must have certain plant-food elements derived from rocks and minerals, elements such as potassium and phosphorous and numerous others in trace amounts. The students are likely to interject "soils" because they hear it used so often. Soils, however, are not vital to the existence of plant life. It is access to the contents of minerals that is the vital factor. Consider why so many rocky mountain ranges with steep slopes are covered by forests. Seeds germinate in cracks and fractures and gain access to the minerals in rocks and through them (next time you see rock masses look carefully at the relationship between plants and fractures). On the other hand, disagrregated rock contributes minerals to soil and soil, in turn, tends to provide easy root access to abudant mineral particles (see chapter on soil).
Add the two solids (rock and minerals) to the list started in procedures number 2 and 3: Air, water, plants, animals, minerals, rocks.
6. Make two columns and divide these identified components into two categories: (1) nonliving, and (2) living.

Nonliving	Living
Air	Animals
Water	Plants
Minerals	
Rocks	

7. Have students make three separate drawings: (1) Rock, (2) Plant, (3) Animal. Ask students to hold up drawing of the thing that they think was here first. List some of their ideas. If they differ, ask for discussion until consensus is reached that rocks were first. What do they think was second? What was third? Plants second and animals third? Why? Most plants can exist without animals, but animals cannot exist without plants. How do animals get nutrition from minerals and the sun? Through eating plants, or, by eating animals that eat plants.
8. Which came first, the Living or Nonliving factors?
9. Analyze the growing of a potted plant from a seed and then a caterpillar occupying a leaf. Establish the logical principle of first things first: Mineral, Vegetable, Animal.
10. Review the two basic objectives. Note that the nonliving essentials for life (air, water, sun, rocks, minerals) form a large part of the natural environment that we live in. Also not that the study of relationships between life and nonlife is a part of the science of ecology.

EXTENSIONS: 1. Make you own growing medium by breaking up some rock and planting some seed to see if you can get it to germinate and grow. A piece of granitic rock would be best if you can obtain one.
2. Have students draw cartoons or do art work interpreting and illustrating basic principles of the earth's life-support system (should show rocks, minerals, water, air, plant with roots, and animal using plant). And sun for completeness if desired.
3. Have students develop riddles, poems, essays about relationships between living and nonliving things.

EXAMPLES: Which came first - the chicken or the egg?
Neither - the rock!
All people should care
About rocks, water, soil, and air
Without the nonliving, no life would there be; no zoos and no jungles to see monkeys up a tree.

Write a short essay pretending that you are a rock. What would you say if you could talk?

EVALUATION: Verbal testing of ideas about the basics of the earth's life-support system: Could wild plants and animals exist without people? Could plants exist without animals? Do animals eat rocks or minerals - directly? Indirectly? Do rocks and minerals need living things? Do living things need rocks and minerals? Do deer need people? Do people need deer (no - discuss this). Could you be here without rocks - minerals?
Why must there be rocks - minerals in order for there to be ice cream? Follow this backward through milk, cows, grass, soils, minerals, and rocks. If they can get this one they can get most others like this.

CONCLUSIONS: 1. By using the logic of the "first-things-first" principle we can reason that it is essential that a life-support system must precede life.
2. The earth's contribution to the life-support system consists of rocks, minerals, water, atmosphere, and the processes that make and manipulate these things to create habitat diversity.
3. Plants are a foot bridge between nonliving rocks - minerals and animals.
4. Almost everything that can be seen or touched has rocks-minerals in its ecological reason for being.
5. It is important that we recognize and appreciate the basic ecological facts of life -we are creatures of the earth's environment and as it goes so go we.
6. Remember - No rocks no ice cream!

Grades:	3-11
Subjects:	Science
Skills:	Analysis, Description, Discussion, Generalization, Making Inferences, Problems Solving
Group Size:	Large Group
Key Vocabulary:	Germinate

RAISIN BREAD "MINING"

OBJECTIVE: Students will be able to understand the concept of nonrenewability and how it might relate to their lives.

CONCEPTS AND UNDERSTANDINGS: 2(c) There is only one "crop" of most geologic (minerals, fuels) resources. 4(a) Discovery is required before new resources can be developed and utilized. If you cannot grow it you must "mine" it (if you want it!) If you cannot grow it and you cannot find it anymore, you must do without it.

METHOD: Teacher-led discussion; development of ecological principles through inductive reasoning and analogy with a slice of raisin bread; application of principles established.

BACKGROUND: In this day of enhances concern for environmental and ecological matters that effect everyday life, resources have been divided into two categories: (1) renewable, and (2) nonrenewable. Renewable resources are, theoretically, capable of being replenished whereas there is only one basic, fixed supply of the nonrenewable resources. By definition, it would seem as though the greatest resource-supply threat accompanies the nonrenewable, fixed-quantity resources. These are the geologic resources represented by rocks, minerals, and energy deposits. Wars are waged in order to control geologic resources considered vital and strategic.

MATERIALS: A piece of raisin bread for each student.

PROCEDURE: 1. Tell the students that the combined bread represents all of the earth and that each piece that they get represents one country of the earth.

2. Hand out one piece of bread to each student and tell them that the raisins represent all of the useful mineral and energy deposits (nonrenewable) in that country.
3. Discuss the types of nonrenewable deposits that they would like the raisins to represent (iron, copper, lead, gold, silver, molybdenum, zinc, tungsten etc., oil, natural gas, coal, geothermal, uranium, construction materials, etc.).
4. Discuss what countries do when they do not have enough of what they need. They trade or, they go to war! Pre and post World War II, Japan is a good example.
5. How might new deposits be found? By studying and exploring. Who does this? Geologists.
6. Tell the students that once their raisins are gone there will not be any more unless they can get them from a neighbor.
7. Should nonrenewable resources be carefully studied?
8. If you know that a resource is limited might you be careful about how it is used?
9. Is it better to conserve than to waste resources of any kind?
10. Tell them that when petroleum is pumped from a place that it is not possible, like it would be in farming, to get more from the same place. Have them remove a raisin and eat it. There is now one less deposit (raisin) in each country and 30 (number of students) less in the world.
11. Jot down several food and mineral resources on the board (corn, peas, copper, tin, wheat, cotton, oil, gold, lettuce, wood, marble, iron, etc.) Make two lists by separating these resources into things that can be taken repeatedly from the same place and those that can be taken only once.
12. Ask which list is renewable and which one is nonrenewable. Label them accordingly.
13. Which uses more nonrenewable resources, a nation where most of the people live on farms or one where most live in cities? Why?
14. Can substitutes sometimes be used if a resource becomes unavailable?

EXTENSIONS: Discuss the conditions under which a renewable resource can become renewable? If we use it faster than nature can replenish the supply. Food is renewable so why are people starving on the earth? Just because something is called renewable does not mean that there cannot be problems? Similarily, just because a geologic deposit is called nonrenewable does not always mean that it will all be used up (there should never be a shortage of salt because there is so much sea water to evaporate). We need, however, to be alert so that we are not caught by surprise! Ignorance should not be an excuse. With good food information we (citizens of the world) ought to be able to look ahead and plan for the rought spots.

EVALUATION: Everything of substance is either a resource or is made from a resource. Identify things in the class room and relate each to either a theoretically renewable or nonrenewable resource? Yes. Then why do we talk about it so much? Because it can be used faster than it is replenished. Knowing this we can study, plan, and manage this long-range, potentially critical problem.

Grades:	6 - 12
Subjects:	Science, Social Studies
Skills:	Analysis, Classification, Comparing Similarities and Differences, Discussion, Generalization, Making Inferences.
Group Size:	Large
Key Vocabulary:	Renewable, Nonrenewable

DIGGING FOR FACTS

OBJECTIVES: Particpants wil be able to: 1) observe that soil is made up of many things, and 2) list the different things found in soil.

CONCEPTS AND UNDERSTANDING: Soil 2A - Soil is made up of many components.

METHOD: Participants will observe and measure the amount of rock particles, sand, silt and clay in various samples of soil and see some of the other components of soil.

BACKGROUND: Information is found in the Soil Chapter.

MATERIALS: Enough trowels, pieces of paper (18 x 20 inches), smaller pieces (5 x 7 inches) of cardstock or construction paper, quart jars, and hand lenses for each group of four to six students. A water source and a clock with second hand.

PROCEDURE: 1. Have each student describe in his or her own words what soil is?
2. Give each group a trowel, hand lens, and piece of large paper and have each group go to a different area of the schoolground and examine the soil at the selected spot. Have them dig down four to six inches and observe how the soil looks and feels and note what they find.
3. Bring a large handful (for small students - two or three handfuls) of soil back to the classroom with them. (This should be enough soil to fill the quart jars about two to three inches deep.)
4. Have each group place their soil in their jar and add water until the jar is almost full.
5. Shake the jar vigorously until all the soil is separated and note the time when the jar is set down.
6. Hold the smaller piece of paper against the jar or tape it to the jar and after 40 seconds mark on the paper the approximate height of the settled soil. The materials below this line are the small rock fragments and sand.
7. At the end of two hours, again make a mark on the paper at the approximate height of the settled soil. The materials between this line and the first one is silt.
8. When the water is clear, make another line on the card at the top of the settled soil layer. This last layer is clay. In many samples, there will also be evidence of organic matter either floating in the water or resting on top of the soil material.
9. Have the students modify their definitions of soil based on this activity.

EXTENSIONS: 1. Have each student bring in a sample of soil from some area around their home and repeat the steps 4 through 3 from the Procedure with this new sample. Have them compare their samples.
2. From a roadside cut or other exposed soil profile, gather a small sample from the surface, and from each foot of depth down to four or five feet, and again go through the settling procedures. Compare the samples.
3. Obtain a soil survey map of the area from which your soil samples were taken in the Procedure and Extensions 1 and 2 and compare differences you found to those indicated by the map.
4. Weigh a small sample of soil taken from a depth of four or five inches and then oven dry it or cover it in the sun and let it dry for a day or so and weigh it again. Does soil contain water? Add water to the same sample until it begins to drip and weigh it again.
5. Fill a small jar about 2/3's full of marbles and add sand from a measuring cup until the marbles are covered. Tap the jar a few times while adding the sand. How much sand was used? What does this tell us about pore spaces in the soil and how sand, silt, and clay are mixed. Do these pore spaces and their size have anything to do with water moving through the soil?

EVALUATION: Have the students develop a list of those things which make up soil or make a drawing of these things.

Grade:	K-12
Subjects:	Science, Arithmetic, Language Arts
Skills:	Analysis, Computation, Description, Drawing, Evaluation, Generalization, Observation, Small Group Work
Group Size:	up to 30
Key Vocabulary:	sand, silt, clay, organic matter, pore space

ROCK GRINDING

OBJECTIVES: Participants will be able to: 1) visualize how soil is formed from rocks, 2) understand the importance of time in the process of soil formation, 3) observe that different types of rock yield different types of soil.

CONCEPTS AND UNDERSTANDINGS: Soil 1A - Soil particles come from the breakdown of rocks, Soil 1B - Time is a major factor in creating soils, Soil 1C - Climatic factors affect the formation of soils, Soil 2B - The types of rock from which soil material is formed influences the type of soil formed.

METHOD: Participants will "make" three kinds of "sedimentary rocks" and physically wear them down into soil material.

BACKGROUND: A general soil map and geology map of your county will help the teacher introduce the relationship of soils to geology for this activity. They will also help you point out that there are several different kinds of soil and rock in your area.

MATERIALS: Three paper cups per group, cement, sand, lime, water, measuring spoons and file for each group.

PROCEDURE: 1. You are going to make three kinds of "sedimentary rock." The file will be used to wear away the rocks.
2. In a cup marked #1, mix 3 tablespoons of cement with ¼ cup of water. The "rock" formed can be called shale.
3. In a cup marked #2, mix 2 tablespoons of cement with 3 tablespoons of sand and add ¼ cup of water. The "rock" formed can be called sandstone.
4. In a cup marked #3, mix 1 tablespoon of cement and 3 tablespoons of lime and add ¼ cup of water. The "rock" formed can be called limestone.
5. Let the materials harden overnight or longer.
6. Tear away the cup from the "rocks" and have each group tell what each rock looks like.
7. Place a piece of large paper on the work space and have each group file one rock at a time for a period of one to five minutes. After each rock is filed, collect the "soil material" in a paper cup before filing the next rock.
8. Discuss with the class such things as; which rock wore away the most, were the "soil materials" the same or different, how fast would running water wear away each rock?

EXTENSIONS: 1. Pour vinegar on the limestone rock and observe what happens.
2. Collect several different kinds of natural rock and attempt to break them down by rubbing them together, filing them or pouring vinegar on them. Keep the soil material that is created by each of these processes in separate containers and compare them.
3. If you can get a piece of natural limestone, heat it and then drop it into cold water. This will simulate the effect of climatic heating and cooling on rocks.
4. Soak a piece of porous rock in water for two or three hours and then freeze it.
5. In each of these extensions you can explore with the class how nature creates the same kind of affect and how it breaks down rocks into soil particles. It would also be helpful to compare the amount of soil they make by filing one of their rocks to a bucketful of soil or to the soil on the schoolgrounds and discuss how long it might have taken to form this soil and where it may have come from.

EVALUATION: Have the students make a chart comparing the texture of the "soil" materials they made. Compare these textures to different soil samples.

Grades:	K-8
Subjects:	Science, Arithmetic
Skills:	Analysis, Comparing Similarities and Differences, Description, Discussion, Generalization, Observation, Experimenting.
Group Size:	up to 30
Key Vocabulary:	Shale, Sandstone, Limestone

WIGGLY WORMS

OBJECTIVE: Participants will be able to: 1) describe the role of living things in soil formation, and 2) observe that the soil is a habitat for living things.

CONCEPTS AND UNDERSTANDING: Soil 2C - Plants and animals are active factors in soil formation, Soil 4B - Soil organisms breakdown organic matter that is created by or results from food cycles, Soil 4C - The life cycle of many plants and animals and of humans takes place almost entirely in or on the soil.

METHOD: The class will make and watch an earthworm farm.

BACKGROUND: Information is found in the Soil Chapter.

MATERIALS: One or more glass gallon jars with wide mouths, pebbles, sand, soil, earthworms, black paper, and a spray bottle with water.

PROCEDURE: 1. Build the following layers in the jar: pebbles, sand, soil, sand, soil, leaves. If you build more than one earthworm farm, use different kinds of soil and different layers or no layers.
2. Mark the layers on the glass with a wax pencil and cover the outside of the jar with black paper.
3. Mist the inside with water, if the soil was moist when you put it into the jar, or wet the entire soil profile. Warning: do not saturate the soil materials.
4. Add up to fifteen earthworms.
5. Every two or three days add some finely chopped up organic matter such as bread crumbs, pieces of fruit, or leaves and mist lightly.
6. Remove the paper for a short period of time each day in order to observe and make notes about the changes that occur. For more dramatic obervations, wait longer periods between observations.
7. If you make more than one earthworm farm, compare the differences between them.

EXTENSIONS: 1. Plant two or three bean seeds in each jar and watch their development.
2. If you have access to a microscope, take a small sample of soil from the jar once a week and observe it closely with the microscope. Return the sample to the jar after this work.
3. Add different amounts of water and/or food to the jars, if you have several of them.
4. Find out what happens when the soil materials in the jar get saturated by adding enough water to create a wet condition.
5. At intervals of two weeks, shine a different colored light on the jar and observe what happens.
6. After a month or so, collect an earthworm dropping and examine it under a microscope.

EVALUATION: Have the students write a story on the earthworm. Describe the changes that took place in the soil after a two month period.

Grades: K-12

Subjects: Science, Language Arts

Skills: Analysis, Application, Description, Evaluation, Generalization, Observation, Writing, Experimenting.

Group Size: not limited

Key Vocabulary:

SUNNY IMPACTS

OBJECTIVES: Participants will be able to observe and describe the relationship between soil and the sun's energy.

CONCEPTS AND UNDERSTANDINGS: Soil 4D - Soil stores heat energy from the sun and releases it slowly as part of our solar energy cycle. Water 5B - Water affects temperatures.

METHOD: Participants will measure the heat storage and release by various soils and compare it to water.

BACKGROUND: Information is found in the Soil, Water and Sun Chapters.

MATERIALS: Several plastic containers at least six inches deep and with 16 square inches of surface area, two or more thermometers with a circular dial and a metal probe, several samples of different texture and color soil.

PROCEDURE: 1. Fill each of the containers with one of the soil samples and one container with water so that the depths of the soil and water are uniform.
2. Place the containers in a dark cabinet for about 48 hours to allow their temperatures to equalize.
3. Measure the temperature of each of the materials at various depths and record the information.
4. Place the containers in the sun and measure the temperatures at the same depths at regular intervals during the day for several days. Be sure to get readings early in the morning.
5. Compare the records.

EXTENSIONS: 1. Ask one or more students to take a container home or set up one at home and make temperature measurements into the evening and earlier in the morning.
2. Measure the temperature of the soil in various locations around the schoolgrounds. Make measurements right at the surface and as deep as your thermometer will penetrate. Do this at selected intervals during the day.
3. Do extension two at different times during the year and compare the results between the times of the year.
4. Collect high and low temperatures for several cities around the country and discuss why some have less variation than others.

EVALUATION: Have the students draw a picture of the heating and cooling cycle created by the sun, either for the whole earth or for just a selected part of it. Have the students theorize why plants may grow better on one side of a building than another, and why certain plants are found in one area and not another (Is it just temperature or do other factors affect this?).

Grade	K-8
Subjects:	Science, Arithmetic
Skills:	Analysis, Application, Comparing Similarities and Differences, Description, Discussion, Evaluation, Experimenting, Generalization, Making Inferences, Observation, Problem Solving
Group Size:	up to 30
Key Vocabulary:	

WHAT PLANT IS IT?

OBJECTIVE: Participants will identify plants by their distinguishable leaf characteristics.

CONCEPTS AND UNDERSTANDINGS: Plant Life #3- Plant communities form important parts of the earth's environment. Understanding A- Plant species are unique and identifiable. Understanding B- Plant communities consist of different combinations of plant species, and are the foundations of biotic communities.

METHOD: Students will describe, draw, and explain uses of plants and their parts.

MATERIALS: Pencils, paper, crayons, illustrated plant guide, paper bag, leaves.

REFERENCES: Plant, animal and insect guides applicable to the local area.

PROCEDURE: 1. Gather a paper bag full of different leaves from around the school grounds.
2. Place the class in a circle and distribute one leaf to each student.
3. Have the student describe the leaf: hairy, smooth, oblong, narrow, short, long, smooth edged, rough edged, etc.
4. Have the students draw the plant that they think the leaf comes from. Is it a tree, a shrub? Grass?
5. Have them draw the types of fruits or nuts that grow on their plants.
6. Have the students describe and draw the types of animal and insects that use the plant for food, shelter, and cover.
7. Using an illustrated plant guide, determine the actual species of the plant from the leaf. Discuss and compare the differences between the actual species information and what the students observed.
8. Take the students on a tour of the school grounds so they can see the plants in their actual form.

EXTENSION: Have the students create a new plant. Describe its environment, uses by animals, insects, etc. What are its specific adaptations to the climate?

Grades:	K-8
Subjects:	Language, Science, Art
Skills:	Analysis, Application, Classification, Comparing Similarities and Differences, Description, Discussion, Drawing, Evaluation, Generalization, Making Inferences, Inventing, Observation, Problem Solving, Reporting, Research.
Group Size:	Any
Key Vocabulary:	Annual, Biennial, Deciduous, Evergreen, Perennial, Plant Community Succession.

ADAPTATIONS OF PLANTS

OBJECTIVES: Participants will be able to explain how plants have adapted through time to their changing environment.

CONCEPTS AND UNDERSTANDING: Plant Life No. 2 - Many factors affect plant growth, reproduction and distribution. Understanding No. 2A - Geologic conditions and changes create dramatic variations in plant life. Understanding No. 2B - Climate and length of day affect growing season. Understanding No. 2C - Plants are interdependent with other plants and animals. Plant Life No. 3 - Plant communities form important parts of the earth's environment. Understanding No. 3B - Plant communities consist of different combinations of plant species, and are the foundation of biotic communities. Understanding No. 3C - Plant communities are constantly changing.

METHOD: Students will divide into groups and will research one of the primary biotic communities to determine how the plants (and by association, animal) have adapted over time to the changing environment.

PROCEDURE: 1. Have the students work in small groups, each group researching a separate biotic community. (Refer to the list of biotic communities in this chapter).
2. Have each group determine what makes the community special and different from other communities. Have them identify the chief plants and animals that inhabit this community. Have them include climatic information about the region where the community is found.
3. Have each group prepare drawings, maps, clipping collage, etc., to illustrate what their community is like.
4. Have each group prepare a short presentation about their community and present it to the other groups.

EXTENSIONS: 1. Have each student keep notes on each presentation to make a biotic community handbook.
2. Divide the students back into their small groups, and ask them to predict and describe the successional changes in their biotic community after disasters like fires, floods, freezes, volcanoes, etc., destroy the existing vegetation.

Grades:	3-12
Subjects:	Language, Reading, Spelling, Art
Skills:	Analysis, Application, Comparing Similarities and Differences, Description, Discussion, Drawing, Evaluation, Generalization, Making Inferences, Listening, Problem Solving, Reporting, Research, Small Group Work.
Group Size:	1 to 4
Key Vocabulary:	Adaptation, Biotic Community, Ecology, Habitat.

FOREST RESOURCES

OBJECTIVES: Students will identify and analyze the socioeconomic issues involved with harvesting a natural resource (timber) in a natural area and the environmental consequences.

CONCEPT: Plant Life No. 4 - Plants provide many essential materials for modern civilizations. Understanding A - Plants provide many of man's basic needs. Understanding C - Man's increased use of plants and their by-products will require more intensive management of earth's plant life.

METHOD: Using a panel debate forum the students will be able to identify the issues involved in managing a resource.

BACKGROUND: An arbitration board meeting is scheduled to determine the use permit application of the Circle G Lumber Company. Circle G wants to harvest timber in Big Rock Mountain Park. (see map) They want to harvest 30% of the timber on the east side of the mountain and 75% of the timber on the west. Circle G proposes to build a lumber mill between the mountain and Mud Lake to process their logs. They also plan to build access roads and a temporary work camp, which they will turn over to the Forest Service within 10 years to be used as a lodge.

The surrounding population areas are all small towns with a high unemployment rate. The lumber mill proposal is very popular, and the citizens are lobbying for Circle G as a way to boost the local economy.

The U.S. Forest Service is agreeable to a cutting operation in the park, but not as extensive as Circle G plans. The Forest Service would be willing to accept a 15% cut on the east side and a 40% cut on the west side, as long as Circle G would conform to a conservation timber harvesting program.

Several local conservation groups are vehemently opposed to the timber cutting proposal. They believe that Circle G intends to deforest large areas of the park and make it visually unpleasing. They also believe that vital wildlife and bird habitat will be lost and Mud Lake will become polluted. The conservation groups have been gaining support from the urban areas and from national conservation groups.

PROCEDURE: 1. Have the students form five groups and assign each group a role: Forest Service, Conservation Group, Circle G Lumber Company, Concerned Local Citizens, and the Arbitration Board. Have each group prepare a defense of their point of view, and have them act it out in front of the the Arbitration Board. Involve the entire class by forming more special interest groups.
2. Poll the students in the class to determine which was the most effective and logical point of view presented, and what would be the long-term affects of that action, should it be adopted.
3. Have class members (not on panel) write about who they thought won the debate and base their choice on sound, logical reasons.
4. Have the students prepare a long-range plan for the area, based on results of the discussions. Include in the plan how they would develop the area, or how they would implement a plan of nonuse, such as making the area a walking park, or nature preserve.

EXTENSIONS: 1. A local affiliate of a national hunting group wants to make Big Rock Mountain Park a selective hunting preserve. They wish to make it an area where people could come to watch the animals (for a fee), and have a guaranteed hunt once a year, with the permit fees to be split with the Forest Service.
2. A developer wants to develop Big Rock Mountain into a ski resort. They propose to cut trails and build a lodge and condos for their clientele, to be rented at a large profit. This profit will be split with the Forest Service at the end of each year. The development of the ski resort will remove vital animal habitat and restrict migratory access. The success of the animal preserve will depend on the popularity of the attraction to a large number of people. The Forest Service will have to determine which plan to accept, based on the principle of highest and multiple use for greatest good of the resource. How would the class determine which action to take?
3. An endangered species of fish has been discovered in Mud Lake. What implications does this have on development of the area?

EVALUATION (Practical Applications):

Students will have to make some observations and determinations of how they would best manage their natural resources. Researching past management decisions would add to the credibility of the arguments pro and con of what to do with a resource.

Grades:	6-12
Subjects:	Language, Science, Health, Social Studies
Skills:	Analysis, Application, Discussion, Evaluation, Making Inferences, Inventing, Problem Solving, Reporting, Debating
Group Size:	Any
Key Vocabulary:	Climax, Conserve, Ecosystem, Environment, Renewable Natural Resource

SHOPPING FOR PLANTS

OBJECTIVES: Students will demonstrate how dependent humans are on plants.

CONCEPTS AND UNDERSTANDING: Plant Life No. 4 - Plants provide many essential materials for modern civilization. Understanding A - Plants provide many of man's basic needs. Understanding C - Man's increased use of plants and their by-products will require more intensive management of earth's plant life.

METHOD: Students will visit several places where plant products are stored and sold, and list all items that are derived from plants and those with non-plant origin.

BACKGROUND: Refer to Plant Life Concept No. 4, Understanding A.

MATERIALS: Paper, clipboards.

PROCEDURE: 1. Have students work as individuals, in pairs or in groups, depending on their age. Each pair or group of students should have one student who can record the names of products.
2. Have students visit a nearby shopping center and ask each group to select a different kind of store: grocery, clothing, drug, hardware, toy store, department store, etc.
3. Have students list all products that are derived entirely from plants, partly from plants, and entirely from another source (animals or minerals). If they are in doubt as to the origin, tell them to guess and circle the product for future reference.
4. After lists have been compiled and returned to school, ask each student (or group) to read their list of products while others note with a checkmark on their own list all of the products being read. Or place the list on large paper or blackboard at front of room.
5. Discuss those products which are doubtful as to origin (i.e., plastics) and ask someone to check it out at the library.
6. With a red marker, underline those products which are essential to man's survival and blue-line under all the products which are not essential but are for our convenience or enjoyment.

EXTENSIONS: 1. Lower-level students (K-3) may want to cut out products from magazines and place on the wall in order of food, clothing, shelter, tools, etc.
2. Have each student go through his home and with the help of a parent, list everything in the home, including parts of the home (walls, floor, roof, etc.) that are derived from plants and from other sources.
3. Ask students to list substitutes for any of the products and the origin of the substitute.
4. Ask students to separate the plant products into natural (vegetable, fruits, etc.) and man-made (brooms, boxes, etc.). Have them determine percentages of plant products vs. non-plant items.
5. Have students list the prices of various articles (price per pound or price per article) to evaluate the relative cost of naturally occurring products vs. man-made articles.
6. Have students list all of the chemicals on the labels.

EVALUATION: Does it cost more for natural plant products or for processed (manufactured) plant products? What is the reason for this? Does it cost more for essential products or nonessential plant products? What conclusion can we make from this? Do processed and manufactured products increase our life style (enjoyment, conveniences)? Do certain products increase our cost of living? How could we conserve our plant life by changing the kinds of products we use? What could we do to conserve some of our plant products? How many plant products could man use without the use of chemicals (preservatives, pesticides, etc.)? Can you find any plant products that can be used to conserve (or preserve) endangered animals (jojoba oil vs. sperm whale oil)?

Grade:	K-12
Subjects:	Language, Reading, Spelling, Mathematics
Skills:	Analysis, Application, Classification, Description, Discussion, Evaluation, Generalization, Making Inferences, Observation, Problem Solving, Reporting, Research, Small Group Work
Group Size:	Any (individual, pairs, or groups)
Key Vocabulary:	food chain, pesticide, conserve

SHOPPING FOR PLANTS

REPORT FORM

Store Visited: _____

Date Visited: _____ Location: _____

Name of Product:	Origin:
Milk (example)	Grass - Cow
Milk Carton (example)	Paper - Tree
_____	_____

COMPOST ENERGY

OBJECTIVES: The participants will explain the role of nongreen plants in decomposition, and how decomposition can provide an energy source.

CONCEPTS AND UNDERSTANDING: Plant Life 1. Plants are vital to living things. Understanding B - Nongreen plants are important agents of decomposition.

METHOD: The students will observe the changes in plant matter as it decomposes in a compost pile, and the nongreen plants that act as decomposers.

BACKGROUND: Nongreen plants (fungi, molds, bacteria) are important agents in the decomposition of plant and animal materials. They can act in aerobic or anaerobic conditions to break down organic material to carbon and energy. Compost is organic material covered with soil and kept moist to promote the growth of nongreen plants and the rapid breakdown of organic material. This breakdown of organic material in nature increases the nutrient content in soils, and the organic material contains vital nutrients needed by plants. Compost has been used for thousands of years as a natural fertilizer in farming, and is presently being tested as an energy source.

MATERIALS: 1. Eight-inch (or deeper) cardboard box. Plant material - fresh grass clippings, leaves. Soil - approximately five pounds.
2. Large plastic garbage bags.

PROCEDURE: 1. Gather the class for the demonstration.
2. Line the cardboard box with one of the garbage bags.
3. Place a layer of soil in the box approximately 2 inches deep in the bottom of the box.
4. Place approximately 4 inches of plant material on top of the soil.
5. Place the thermometer in the plant material and record the temperature. (It should be at room temperature at this stage.)
6. Pour approximately 2 cups of water on the plant material.
7. Cover the plant material with about 4 inches of packed soil.
8. Place the box in the other plastic bag and seal tightly.
9. Leave the bag sealed for 2 to 3 weeks.
10. Open the bag and take off all but 1 inch of the soil covering the plant material.
11. Place the thermometer through the soil into the plant material and record the temperature.
12. Remove the remaining soil and examine the plant material. It should be hot and smell fermented. It should also have various nongreen plants growing on it. Examine the plant material and see if it is still recognizable, and if any has decomposed totally.
13. Discuss the findings with the class. What could be done with the heat (energy) that is generated by decomposition? We know that compost is used in agriculture as a fertilizer, but what use does it have in a natural ecosystem? What happens to dead trees in the forest? What kinds of biomes have the fastest decomposition rate? Which are the slowest? Why?

EXTENSIONS: 1. Have the students visit a farm where compost or silage is being processed, and where they can see it being used as fertilizer or feed.
2. Have the students examine their surroundings to see if they can find any nongreen plants at work.

3. If possible, take the students on a walk through a forest and see if they can find plants in various states of decomposition.
4. A comparison of how plants grow in compost material versus how they grow in soil can be made by using a control bag of soil along with the compost bag during the experiment.

EVALUATION: How do nongreen plants use other organic material for food? How do humans and animals use this decomposed material? What are the best conditions for decomposition? How can compost be economically used?

Grades:	K-12
Subjects:	Language, Science
Skills:	Analysis, Description, Discussion, Making Inferences, Observation, Problem Solving, Experimentation.
Group Size:	Any
Key Vocabulary:	Aerobic, Anaerobic, Compost, Decomposition, Saprophyte.

PLANT BRAKES

OBJECTIVES: Participants will be able to: 1) observe the relationship between soil, soil depth and plant growth, and 2) describe the role of soil and water in plant growth.

CONCEPTS AND UNDERSTANDING: Plant Life Concept No. 3: Plant communities form important parts of the earth's environment. Soil 2C - Plants and animals are active factors in soil formation, Soil 3B - The soil's depth affects its ability to perform, Soil 4C - The life cycle of many plants and animals and of humans takes place almost entirely in or on the soil, Water 4A - Living cells depend upon water.

METHOD: Participants will grow plants in a variety of soils. This activity can be conducted in conjunction with the earthworm farm activity.

BACKGROUND: Information is found in the Soil Chapter and in the Water Chapter.

MATERIALS: Several large glass or plastic (transparent) containers with wide mouths, water source, bean seeds, staking materials, cheesecloth, several soil samples of different textures, small amounts of different fertilizers, pebbles, and some rocks that just fit into the containers.

PROCEDURE: 1. Fill the containers about two-thirds full with different layers and/or kinds of soil. Use the cheesecloth to prevent the soil from mixing in with the pebbles in some of the layers. Use the rocks to create a soil that is shallow over a rock formation.
2. Establish a notebook for each container and keep accurate notes of planning dates, water times, amount of water added, amount of fertilizer added, etc.
3. Plant three to four seeds in each container and water the soil. Be careful not to saturate the soil. Place one or two of the seeds close to, but not quite touching, the side so you will be able to see the roots soon after germination.
4. Place the containers in a well-lighted area and observe what happens. Measure the depth of root development as well as the height of the plants.

EXTENSIONS: 1. Using containers with the same kinds of soil material, grow some plants in well-lighted areas and others in dark areas.
2. Map the location, kinds, and density of different plants around the schoolyard or around one of the buildings.
3. Using containers with the same kinds of soil material, grow some plants but vary the amount of water and the timing of waterings.
4. Using containers with the same kinds of soil material, grow some plants but use water with varying quality of irrigation. You can change water quality by adding table salt. Measure and keep track of how much salt is added to different water supplies.
5. On a field trip, take time to note different plant communities and the kind and depth of soil where they are growing. Does soil influence plant growth?

EVALUATION: Have the students theorize or find out how different texture soils and soils of varying depths might affect users of the land such as: farmers, home builders, road builders, ranchers, home gardeners, etc. Write a story on the importance of land and its soil in the life of a plant, animal or person.

Grade: K-12

Subjects: Science, Arithmetic, Language Arts

Skills: Analysis, Application, Comparing Similarities and Differences, Computation, Description, Experimentation, Generalization, Making Inferences, Mapping, Observation, Writing

Group Size: almost any

Key Vocabulary:

PHOTOSYNTHESIS AND TRANSPIRATION

OBJECTIVES: Participants will be able to 1) observe the effect of light on plants, 2) illustrate the exchange of gases between the atmosphere and the plant.

CONCEPTS AND UNDERSTANDINGS: Plant Life 1. Plants are vital to living things. Understanding 1A - Only green plants can use the sun's energy to produce food through photosynthesis. Understanding 1C - Plants are apart of many natural cycles.

METHOD: Seedlings will be grown in the classroom under varied conditions to illustrate the effects of different environmental factors. This activity can be conducted as either a demonstration or a hands-on experience.

BACKGROUND: Plants provide a renewable source of food energy for many forms of life. Green plants utilize the sun's energy and the gases in the atmosphere to produce food through photosynthesis and exchange gases in the atmosphere in the associated process of transpiration.

MATERIALS: Two or more 6-inch pots, 50 (or more) pea seeds, vermiculite soil mixture (or potting soil), a sprinkler (a jar with small holes poked in the lid would be effective), a dark area (a large cardboard box or a cabinet that can remain closed for a week), a glass bottle or jar, paper, pencils, crayons.

PROCEDURE: 1. Have the class divide into small groups (if not conducting this experiment as a demonstration.) Have each student make an illustrated log of events from germination of the seedlings to the end of the experiment.
2. Germinate pea seeds by placing them onto damp paper towels in a tray or shallow dish and covering them with warm tap water. Keep covered with warm water and in an indirectly lit place. A "hook" should appear in two to three days. After the "hook" appears, the seeds are ready to be planted in the pots.
3. Prepare two pots by placing paper towels as a lining for each pot. Fill with the vermiculite soil mixture up to 2 1/2 inches from the top.
4. Place the seeds carefully on top of the soil mixture. Cover with 1/4 to 1/2 inches of soil mix.
5. Sprinkle water over the top of the soil until the soil is well saturated.
6. Place one of the pots in a well lit place. (A window sill or a desk top will do.)
7. Place the other pot in the designated dark area and leave it completely in the dark for one week to ten days.
8. At the end of one week or ten days, remove the pot from the designated dark area and compare it with the pot of seedlings that were grown in the light.
9. Have the class discuss the differences and make a drawing to illustrate the differences between the two sets of seedlings.
10. Leave the pot that was in the dark in the light for a few days, and compare the results.
11. Remove one seedling from each pot and compare the root structure of the dark grown seedlings and the light grown seedlings.
12. Place a glass bottle over one of the seedlings, and place it in the sunlight.
13. Notice the condensation that occurs on the inside of the bottle. The condensation is water vapor being given off by the plant when it exchanges oxygen for carbon dioxide. (Transpiration)

EXTENSIONS: 1. Take the class out to a grassy area on the school grounds. Dig up a shovelful of grass-covered soil. Have the class examine the depth of the roots and their structure. How do they differ from the pea seedling roots? How does grass differ physiologically from the pea seedlings? (stems, leaves, etc.) Do they have the same photosynthetic process?

2. Take the class to a treed or forested area. Compare the effect of light on identical seedlings growing in the shade of a tree and seedlings growing in sunlight.

Grades:	K-12
Subjects:	Language, Art, Science
Skills:	Application, Comparing Similarities and Differences, Making Inferences, Observation, Small Group Work, Experimentation.
Group Size:	2 to any
Key Vocabulary:	Photosynthesis, transpiration, renewable resource.

PLANT ENERGY

OBJECTIVES: Participants will explain how coal and petroleum reserves were formed from plant materials and how these resources are used.

CONCEPTS AND UNDERSTANDING: Plant Life #4 - Plants provide many essential materials for modern civilization. Understanding 4B - Ancient plants, converted to coal, provide a useful source of stored energy.

METHOD: Students will observe a demonstration of how coal and petroleum reserves were formed, and will participate in discussions on how these reserves are accessed and used, and how other forms of energy compare with them.

BACKGROUND: Plants provide energy in many forms. Through photosynthesis, they provide food energy as carbohydrates. As plant products, they provide energy in such forms as wood for fire and fermented grains for gasoline (gasahol). As a component of the organic matter that makes fossil fuels, they form coal and petroleum reserves. These coal and petroleum reserves have been the major sources of energy for man for at least two centuries, but are now recognized as a nonrenewable resource, and new forms of energy harvesting are being explored (i.e., solar, nuclear). Until these new forms of energy become cost efficient, man must learn to use the reserves of coal and petroleum wisely.

MATERIALS: 1 Glass (a large tumbler), clean sand, soil, grass clippings and leaves, pencils, paper, crayons.

PROCEDURE: 1. Gather the class into a circle.
2. Place a thin layer of soil in the bottom of the tumbler.
3. Place a moderately thick layer of leaves and grass clippings on top of the soil layer.
4. Place alternating layers of soil and sand on top of the leaves and grass clippings. Pack the layers down.
5. Have the students examine the glass. The different layers of the soil will illustrate sedimentation. The layer of organic material (leaves and grass clippings) will illustrate how plant material was trapped within the sedimentation process, and which has over time and under heat and pressure become coal and petroleum reserves.
6. Have each student describe how he or she would extract the "coal". Discuss how coal is mined. Discuss the differences between each student's idea of how to get the coal out.
7. Have the students go back to their desks and draw the model, and have them illustrate how they would extract the coal.
8. Ask the students to draw how they would use the energy that they would get from the coal, and have them illustrate how coal is being used presently.
9. Tell the students that the "coal" in the glass is equivalent to two years of energy use for one person. This reserve is all each one of them has as a usable energy source for the present. Have them write how they would use this resource, and what they would do to prepare for its eventual loss (i.e., make new forms of energy).
10. Have each student read their ideas to the class, and discuss the practical uses.

EXTENSIONS: 1. Have the class prepare lists of renewable and nonrenewable plant-related energy producing items (i.e., coal, wood, food).
2. If applicable, gather the class around a campfire and observe the energy that is released when the plant products are burned.
3. Use the related activity "Select a site" from the Arizona Energy Department.

EVALUATION: How are energy reserves formed from plants? How do humans use this energy? What will happen when the reserves are all utilized? What alternative sources of energy are being explored?

Grades:	K-12
Subjects:	Language, Science, Art
Skills:	Analysis, Application, Drawing, Evaluation, Making inferences, Observation, Problem Solving, Reporting, Writing.
Group Size:	Any
Key Vocabulary:	Renewable Resource, Nonrenewable Resource, Reserve.

PLANT COVER

OBJECTIVES: Participants will be able to discuss the different aspects of plant cover in soil and water conservation.

CONCEPTS AND UNDERSTANDING: Plant Life No. 1: Plants are vital to living things. Understanding 1C: Plants are a part of many natural cycles.

METHODS: Barley seedlings will be grown in the classroom and used in a demonstration of soil binding and cover protection. This activity is best conducted as a demonstration.

BACKGROUND: Plants are an important link in the water cycle, affecting the movement of water to and from the atmosphere, and through the soil. Plants also act as physical barriers to erosion by binding the soil and forming a cover over the ground.

MATERIALS: 2-5 inch deep clear glass or plastic baking dishes, 2 pounds of moderate sized gravel, 2 pounds of clean sand, 2 pounds of vermiculite soil mixture (or potting soil), 2 packages of barley seeds, and a sprinkler (a jar with holes punched in the lid would be sufficient).

PROCEDURE: 1. Prepare the seedbeds by first placing a layer of gravel in the bottom of each glass dish. Then place a 2 inch layer of sand on top of the layer of gravel. Finally, place a 1½ inch layer of soil mixture on top of the sand.
2. Sprinkle the contents of the two seed packages on the top of one of the seedbeds. Leave the second dish without seeds as a control in the demonstration.
3. Cover the seeds lightly with 1/8 to 1/4 inch of soil mixture.
4. Water the dish with seeds in it by sprinkling water on the top until the soil appears to be saturated. Repeat watering dish with the seeds in it every couple of days for 7-10 days.
5. While the seedlings are growing, have the students examine the fiberous, mat forming roots through the sides of the glass dish.

DEMONSTRATION: 6. Sprinkle water on the tops of both dishes. Note the "craters" that the impact of the water has made on the dish without seedlings. The dish with the seedlings in it will show little or no cratering or impact damage. These impact "craters" break up the soil surface, allowing soil particles to be washed away during a rain storm. By the plants breaking the impact of the raindrop, erosion is reduced where plant cover is greatest.
7. Sprinkle both dishes until the soil is saturated and has about 1/2 inch of standing water on the top.
8. Tilt each of the dishes at a slight angle to demonstrate runoff and erosion. The dish with the barley seedlings will have less runoff, and the runoff will be cleaner than the runoff from the dish with no seedlings. Note that the soil in the control dish physically moves, where the soil bound by the seedlings in the other dish is held in place.
9. Place the dishes flat again and apply approximately 1/4 inches of water to each dish. Observe how the water travels down through the soil and sand to the bottom of the dish. The dish with the seedlings in it should not drain as much water to the bottom as the dish with no seedlings. The water that drains to the bottom will also be cleaner in the dish with seedlings in it than the dish with no seedlings.

EVALUATION: Plants play an important role in maintaining the water cycle; in soil stablization and water quality they act as binders, protectors, and filters. The urbanization of formerly plant covered areas, combined with increased demands of water resources has changed water quality and quantity of groundwater recharged each year.

EXTENSION: 1. Take the group into different areas where lawns and bare grounds may be compared. Observe various conditions of erosion and water quality (clear, clean runoff) under the different vegetative cover.
2. Using pictures and/or newspaper or magazine articles, show areas of damage by erosion. Example: Mud slide areas in Southern California, farm and ranch lands in the Midwest.

Grades: 3-12

Subjects: Language, Science

Skills: Analysis, Description, Evaluation, Making Inferences, Observation, Problem Solving, Experimentation

Group Size: Any

Key Vocabulary: Cover, Erosion, Natural Cycles

PLANTS - WHO NEEDS THEM?

OBJECTIVES: Students will show how most plants are vital to other plants and to animals. They may also show that some plants are more important to animals than others.

CONCEPTS AND UNDERSTANDINGS: Concept #1- Plants are vital to living things. Understanding 1D- Plants are a renewable natural resource. Concept #4- Plants provide many essential materials for modern civilization. Understanding 4A- Plants provide many of man's basic needs.

METHODS: Students will list and rank plants in order of their importance to man. This activity can be accomplished indoors or outdoors. If time permits, it will be beneficial to do the exercise indoors for "practice" then go outdoors to look at the real world.

BACKGROUND: The entire discussion on the concept and understanding will provide a basis for initiating and directing this activity. More advanced students should learn the meaning of parasite, saprophyte, herbivore, and symbiosis.

MATERIALS: Writing paper, pens, and a "clipboard" if the activity is to be accomplished outdoors. A simple clipboard can be constructed from a piece of cardboard and a metal clasp or large paper clip.

PROCEDURE: (indoors): 1. Divide the class into small groups. One of the students should be the "recorder."
2. Ask each group to list 5 to 20 (depending on grade level) of the most important plants they can think of, and why these plants are important to a particular animal. Do not list the same plant or animal twice. The "recorder" should record their answers. Examples can be general ("tree") or more specific ("oak tree") depending on the age of the student.
3. Ask them to include at least one plant that is important for the survival of another plant (this may be the most difficult question); do not include the same plant twice.
4. After completing their lists, have the students place the number 1 in front of the "most important" plant on their list, the number 2 in front of the second most important plant, etc. They should be prepared to explain why these plants are important.
5. When all the groups have finished with their lists, ask one group to give the name of the first plant on their list and write the plant name on the board. How many other groups had the same name included on their list?

EXTENSIONS: 1. Ask the groups to go outside to a nearby park or several backyards and list all the plants they see that are being used by another plant or animal (i.e., mistletoe on a cottonwood tree, leaf hoppers on a weed, fungus on a stump, bird's nest in a tree, etc.).
2. Ask individuals to make a list of everything they use during the day and mark which items are derived directly from plants, which are derived indirectly, and which items are not made from plants. Include things they wear, eat, and use in any way. Some items may require a little research at the library to determine where they originate. (Also, see activity: Shopping For Plants.)

EVALUATION: (Practical Application): Students may have to make some very close observations of plants and animals to determine the extent to which one is using the other. A vine may be using a tree for support; a bird may use the tree for a nest site and as a source of food; the bird may feed on insects that endanger the tree - an example of symbiosis.

(Another activity.)

Grades:	6-9
Subjects:	Language, Arts, Science
Skills:	Analysis, Application, Description, Discussion, Evaluation, Making Inferences, Problem Solving, Reporting, Small Group Work, Writing.
Group Size:	Any
Key Vocabulary:	Adaptation, Ecology, Energy Cycle, Food Chain, Habitat, Niche.

PLANTS - WHO NEEDS THEM

GROUP INVENTORY FORM

Students should record all the plants in the area and try to determine how different animals use the plants:

Name of plant:	Animal that uses plant:	How plant is used:
Example:		
Tree	Bird	Nest site
Rosebush	Aphids	Food

PLANTS - WHO NEEDS THEM

SUMMARY FORM OR HOW ANIMALS USE PLANTS

Place names of animals in the left hand column and plants across the top. Write in the space under each plant how each animal uses the plant. Examples are noted in the first spaces.

Animal	Tree	Rosebush	Grass
Birds	nest		food (seeds)
Bugs	escape	food	

RAINBOW CELERY

OBJECTIVES: Participants will be able to explain and observe how plants take up water from their environment.

CONCEPTS AND UNDERSTANDING: Plant Life #1 - Plants are vital to living things. Understanding #1C: Plants are a part of many natural cycles.

METHODS: Utilizing a simple demonstration, students will be able to observe the process of plants taking up water from their environment and how water is routed through the plant.

MATERIALS: Celery stalk, razor blade, small styrofoam cups, several food colors, water.

PROCEDURE: 1. Prepare cups by placing about 20 drops of different colored food colors in 3 or more cups. Fill the cups approximately 3/4 full of water and stir.
2. Prepare the celery by making 3 or more longitudinal cuts in the base end of a celery stalk. Make 1 more section than the number of different dyes used. Leave the top of the celery whole, as it is where the different colors will end up.
3. Place each of the sections carefully in a different cup of coloring, taking care not to tear the top of the stalk. Place 1 section in plain water as a control.
4. Observe the rise of the colors along the different sections, and how they merge in the top.
5. With a razor blade, cut the celery horizontally, and observe the "veins" of the plant (the xylem and phloem).

EXTENSIONS: Discuss how water travels through plants. What makes the water "flow" upward against gravity? Why do plants wilt? Can plants get too much water? What happens when water borne pollutants get taken up by plants? How does this affect the food chain?

Grades:	K-12
Subjects:	Language, Science
Skills:	Analysis, Description, Discussion, Experimentation, Generalization, Making Inferences, Observation, Problem Solving.
Group Size:	Any
Key Vocabulary:	Cycles, Hydrologic (water) cycle, pollution, transpiration

PLANT MURAL

OBJECTIVES: Participants will be able to observe and name the types of plants in their immediate surroundings.

CONCEPTS AND UNDERSTANDINGS: Plant Live Concept No. 3: Plant communities form important parts of the earth's environment.
Understanding 3A: Plant species are unique and identifiable.
Understanding 3B: Plant communities consist of different combinations of plant species, and are the foundation of biotic communities.

METHOD: Students will tour the school grounds and their home surroundings and learn to identify the plant species present.

PROCEDURES: 1. Discuss general plant identification terms with the class, i.e., shrubs, trees, grass, cactus, evergreen, deciduous.
2. Take the class on a tour of the school grounds, noting the different types of plants.
3. Either individually or in groups, have students gather leaves (or needles) from as many different plants as they can find. Have the students designate a recorder for each group and have that student record the plant type the leaf was gathered from.
4. Using a standard guide of plants of Arizona, or any other pictorial guide, try to identify the plants as to which family they belong to; i.e. elms, pines, palo verde, bermuda, roses, etc. A guest speaker from a local nursery could be an informative help in identifying ornamental species.
5. Have the students examine the leaves for adapative characteristics - hairs, waxy coatings, thickness - which are beneficial to the plant by reducing insect damage, retaining water, and as protection against heat or frost damage.
Note: Many common landscape plants found in Arizona are adapted for the climatic conditions here (warm dry winters and hot wet summers). These plants can be identified by certain characertistics.
These adaptations are primarily used in retaining water, blocking light and heat, and drought dormancy. For example, Jojoba and natal plum shrubs have thick, waxy leaves that block the light from penetrating through the leaf, which keeps it cooler and helps it retain water. Ocotillo are an example of drought dormancy as they shed their leaves when in drought conditions to conserve water.
Other adaptations are hairs or spines on the surface of the leaf that can help the leaf repulse insects, and make the leaf less palatable to herbivores (plant eaters).
6. Have each group preserve their leaf specimens by placing them between two sheets of clear contact paper, or between two sheets of waxed paper, which is lightly ironed to seal the paper. (Caution - when using waxed paper, be sure the plant material is completely dry. If not, the plant material can rot.)
7. Have each group write a short description of the plant for each leaf, i.e. where the plant for each leaf was collected, who collected it, and when it was collected. Tape this to the leaf specimen.
8. Have the groups collectively collaborate on making a plant map of the school campus and surrounding areas where they have identified the plant species.
9. Collect the leaf specimens, descriptions, and the map, and bind them in a binder to make a permanent guide to the campus plants.

EXTENSIONS: 1. For lower levels (K-3), the autumn season's color can be illustrated by having the children collect mulberry leaves (or any large leaves) and placing them and orange, red, and yellow crayola shavings between waxed paper and lightly ironing it. When placed in a window it is especially colorful.

2. An informative, interesting bulletin board can be made by placing a large campus plant map on a bulletin board and surrounding it with the leaf specimens gathered by the students.

Grades:	K-12
Subjects:	Language, Art, Science
Skills:	Analysis, Application, Classification, Comparing Similarities and Differences, Description, Discussion, Drawing, Evaluation, Generalization, Making Inferences, Mapping, Observation, Problem Solving, Research
Group Size:	Any
Key Vocabulary:	Annual, Chlorophyll, Deciduous, Plant Communities

THE INTERDEPENDENCE OF ANIMALS AND PLANTS

OBJECTIVES: To demonstrate the associations between plants and animals.

CONCEPTS AND UNDERSTANDING: Plant Life #1: Plants are vital to living things. Understanding D: Plants are a renewable natural resource. Plant Life #2: Many factors affect plant growth, reproduction, and distribution. Understanding 2D: Diversity of plant life influences the diversity of animal life. Plant Life #3: Plant communities form important parts of the earth's environment. Understanding 3B: Plant communities consist of different combinations of plant species, and are the foundation of biotic communities. Understanding 3D: The diversity of plant life influences animal diversity.

METHOD: Students will research different wildlife species and their interdependence on plant life for their habitat.

MATERIALS: Paper, pencils, pens, crayons, magazines, library access, maps.

PROCEDURE: 1. Have the students work individually or in small groups, and assign each a wild animal or bird. Ask them to prepare a short presentation on that animal or bird, on how it uses plants for food, shelter, and refuge from predators.
2. Have the students research their "topic" in the library or in the classroom, using such references as the encyclopedia, nature books, and magazines.
3. Have the students prepare a mosaic depicting the animal in its habitat. Use drawings, magazine clippings, or natural materials (leaves, twigs, grass, etc.) to make the mosaic. During the student's presentation, have him (or her) explain the mosaic.

EXTENSIONS: 1. Upper-level students (6-12) should research a wildlife species individually in the library, and present a longer, more detailed presentation (i.e., migratory patterns, possible origins of the species, habitat modifications, preservation techniques, etc.) accompanied by visual aids. The students could make a wildlife handbook from their notes of each presentation.
2. Lower-level students (K-3) could be taken on a nature walk around the school grounds to see the wildlife that inhabit it, and the plants that they use (i.e., birds in trees, caterpillars on leaves, bugs in the grass, lizards in the shrubs, etc.). Ask them to discuss what they saw and draw pictures of the wildlife and the plants they used.

EVALUATION: What types of plants do wildlife use? Are there different plants used for different wildlife species? Does wildlife use certain plants for food and different plants for cover? Do wildlife have camouflage adaptations for the plants they live in? If the plants were to change or die, would the wildlife change? What happens when there is a fire in the forest? How does wildlife adapt?

Grades:	K-12
Subjects:	Language Arts, Science, Social Studies
Skills:	Analysis, Application, Description, Discussion, Drawing, Evaluation, Generalization, Making Inferences, Listening, Observation, Problem Solving, Reporting, Research, Small Group Work, Writing.
Group Size:	Individuals to small groups
Key Vocabulary:	Adaptation, Biotic, Community, Carrying Capacity, Diversity, Ecology/Ecosystem, Food Cycle, Food Chain, Habitat, Natural Cycle, Succession.

Adapted from: "AND THE WOLF WORE SHOES" (Project Wild)
(c) Western Regional Environmental Education Council, 1983

OBJECTIVES: Students will be able to: 1. Distinguish between animals based on "real life" and those based on "make believe". 2. Give examples of real and make-believe animals and their characteristics. 3. Students will also recognize the use and influence of animals in literature and storytelling.

CONCEPTS AND UNDERSTANDING: Animal Life Concept No. 5 - Animals are of value to man in many ways. Understanding B - The ties between humans and animals vary, but are expressed in religion, life styles, art, music, drama, literature, and other means of creative expression.

METHOD: Students divide books into those about "real" and those about "make-believe" animals, and then distinguish between real and fictitious animal characteristics.

BACKGROUND: Refer Animal Life Concept No. 5, Understandings A, B.

Portrayal of animals in books, fairy tales, comics, cartoons, movies, and other media may have an influence on the perceptions young people have of those animals.

The major purpose of this activity is to give students experience in actively distinguishing between realistic and fictionalized portrayal of animals in literature.

MATERIALS: Childrens books and comics about or including animals, both real and "make-believe".

PROCEDURE: 1. Put out a small stack of books for every group of two to four students. Each stack should have some books that portray animals realistically, and some that give the animals unrealistic qualities, like human attributes.
2. Let the students look through the books in their stack and try to divide them into books about real animals, or animals that act in real ways, and books that are about imaginary or make-believe animals, or even real animals that act in make-believe ways. If necessary, help the students to make their distinctions.
3. Work quietly with each of the groups to check their classifications into "real" or "make-believe".
4. Ask any volunteer from any of the groups to give an example of a "make-believe" animals. Talk about what make the animal "make-believe".
5. Ask any volunteer from any of the groups to give an example of a "real animal". Talk about what makes that animal real.
6. Using a chart like the one below, ask the students for examples from the books in their stack to fill in the blanks in the chart:

	SOUND	SHELTER	APPEARANCE	ACTIONS	FOOD	LOCO-MOTION
REAL						
MAKE BELIEVE						

7. Talk with the students about their ideas concerning the importance of being able to tell when something is real and something is make-believe. Talk about why that is important to remember when learning about animals and how they live.

8. Discuss with the students both wild and domestic animals in literature and storytelling.

CONCLUSIONS: Animals play a major role in literature and storytelling. Many times animals are portrayed in a "make-believe" manner that portrays them unrealistically.

EXTENSIONS: 1. Pick animals in your favorite stories, like Stuart Little, Charlotte's Web, Wind in the Willows, and Winnie the Pooh. Are these "real" or "make-believe"? In what ways?

2. Have students find other examples of expression (music, art, cartoons, and television characters) that portray animals in both realistic and make-believe manners.

EVALUATION: Name three things a make-believe animal does that a real-life animal cannot do.

Grades:	2-5
Subjects:	Language Arts, Reading, Science
Skills:	Analysis, Application, Classification, Comparing Similarities and Differences, Public Speaking, Small Group Work, Graphing
Group Size:	Small groups
Key Vocabulary:	Real, imaginary

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Adapted from: OH DEER (Project Wild)
(c) Western Regional Environmental Education Council, 1983

OBJECTIVE: Students will be able to: 1) identify and describe food, water, and shelter as three essential components of habitat; 2) describe the importance of good habitat for animals; 3) define "limiting factors" and give examples; 4) recognize that some fluctuations in wildlife populations are natural as ecological systems undergo a constant change.

CONCEPTS AND UNDERSTANDINGS: Animal Life No. 1 - Animals are dependent upon their habitat for existence. Understanding B - The five essentials of animal habitat necessary to all species are: food, water, shelter, space or territory, and the arrangement of these elements in relationship to each other. Understanding D - Animal species and their numbers are affected by changes in the quality and quantity of their habitat.
Animal Life No. 2 - Animal species are interdependent with one another and with their environments. Understanding A - Living things exchange energy and matter with the environment and with each other. Understanding C - Animals are a part of the diversity and balance of ecological systems.
Animal Life No. 3 - Animal populations and their environments are not static, but in constant change. Understanding A - Changes in the environment affect living things. Understand C - Animal population will increase until some limiting factor is imposed.

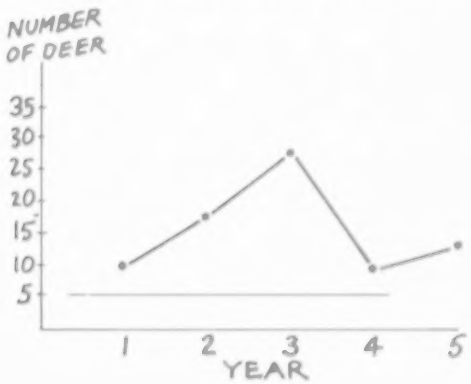
METHOD: Students become "deer" and components of habitat in a highly-involving physical activity.

BACKGROUND: Refer to Animal Life Concept No. 1, Understandings B, C, D, and Concepts No. 3, Understandings A, and C.

MATERIALS: area -- either indoors or outdoors -- large enough for students to run; e.g., playing field; chalkboard or flip chart; and writing materials.

PROCEDURE: 1. Begin by telling students that they are about to participate in an activity that emphasizes the most essential things that animals need in order to survive. Review the essential components of habitat with the students: food, water, shelter, and space in a suitable arrangement. This activity emphasizes three of those habitat components--food, water, and shelter--but the students should not forget the importance of the animals having sufficient space in which to live, and that all the components have to be in a suitable arrangement or the animals will die.
2. Ask your students to count off in four's. Have all the one's go to one area; all two's, three's, and four's go together to another area. Mark two parallel lines on the ground or floor ten to twenty yards apart. Have the one's line up behind one line; and the rest of the students line up behind the other line.
3. The one's become "deer". All deer need good habitat in order to survive. Ask the students what the essential components of habitat are again: food, water, shelter, and space in a suitable arrangement. For the purposes of this activity, we will assume that the deer have enough space in which to live. We are emphasizing food, water, and shelter in order to survive. When a deer is looking for food, it should clamp its hands over its stomach. When it is looking for water, it puts its hands over its mouth. When it is looking for shelter, it holds its hands together over its head. A deer can choose to look for any one of its needs during each round or segment of the activity; the deer cannot, however, change what it is looking for; e.g., when it sees what is available, during that round. It can change again what it is looking for in the next round, if it survives.
4. The two's, three's, and four's are food, water, and shelter-components of habitat. Each student gets to choose at the beginning of each round which component he or she will be during that round. The students depict which component they are in the same way the deer show what they are looking for; that is, hands on stomach for food, etc.

5. The game starts with all players lined up on their respective lines (deer on one side; habitat components on the other side)--and with their backs to the students at the other line.
6. The facilitator or teacher begins the first round by asking all of the students to make their signs--each deer deciding what it is looking for, each habitat component deciding what it is. Give the students a few moments to get their hands in place--over stomachs, mouths, or over their heads. (As you look at the two lines of students, you will normally see a lot of variety--with some students water, some food, some shelter. As the game proceeds, sometimes the students confer with each other and all make the same sign. That's okay, although don't encourage it. For example, all the students in habitat might decide to be shelter. That could represent a drought year with no available food or water.)
7. When you can see that the students are ready, count: "One. . .two. . .three." At the count of three, each deer and each habitat component turn to face the opposite group, continuing to hold their signs clearly.
8. When deer see the habitat component they need, they are to run to it. Each deer must hold the sign of what it is looking for until getting to the habitat component person with the same sign. Each deer that reaches its necessary habitat component takes the "food," "water," or "shelter" back to the deer side of the line. This is to represent the deer's successfully meeting its needs, and successfully reproducing as a result. Any deer that fails to find its food, water, or shelter dies and becomes part of the habitat. That is, in the next round, the deer that died is a habitat component and so is available as food, water, or shelter to the deer who are still alive. NOTE: When more than one deer reaches a habitat component, the student who gets there first survives. Habitat components stay in place on their line until a deer needs them. If no deer needs a particular habitat component during a round, the habitat component just stays where it is in the habitat. The habitat person can, however, change which component it is from round to round.
9. You as the facilitator or teacher keep track of how many deer there are at the beginning of the game, and at the end of each round you record the number of deer also. Continue the game for approximately 15 rounds. Keep the pace brisk, and the students will thoroughly enjoy it.
10. At the end of the 15 rounds, gather the students together to discuss the activity. Encourage them to talk about what they experienced and saw. For example, they saw a small herd of deer (seven students in a class size of 28) begin by finding more than enough of its habitat needs. The population of deer expanded over two to three rounds of the game, until the habitat was depleted and there was not sufficient food, water, and shelter for all the members of the herd. At that point, deer starved or died of thirst or lack of shelter and they returned as part of the habitat. Such things happen in nature also.
11. Using a flip chart pad or an available chalkboard, post the data recorded during the game. The number of deer at the beginning of the game and at the end of each round represent the number of deer in a series of years. That is, the beginning of the game is year one; each round is an additional year. Deer can be posted by five's for convenience. For example:



The students will see this visual reminder of what they experienced during the game: the deer population fluctuated over a-period-of years. This is a natural process, as long as the factors which limit the population do not become excessive, to the point where the animals cannot successfully reproduce. The wildlife populations will tend to peak and rebuild, peak and rebuild, as long as there is good habitat and sufficient numbers of animals to successfully reproduce.

12. In discussion, ask the students to summarize some of the things they have learned from this activity. What do animals need to survive? What are some of the "limiting factors" that affect their survival? Are wildlife populations static, or do they tend to fluctuate, as part of an overall "balance of nature?" Is nature ever really in "balance," or are ecological systems involved in a process of constant change?

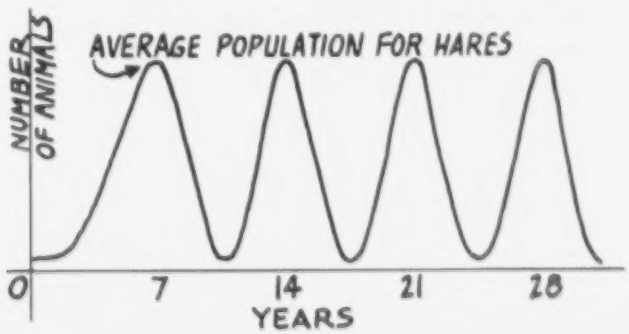
CONCLUSIONS: 1. Wildlife population fluctuates naturally in response to "limiting factors" in their habitat.

Discuss the "balance of nature." Is it ever in "balance?"

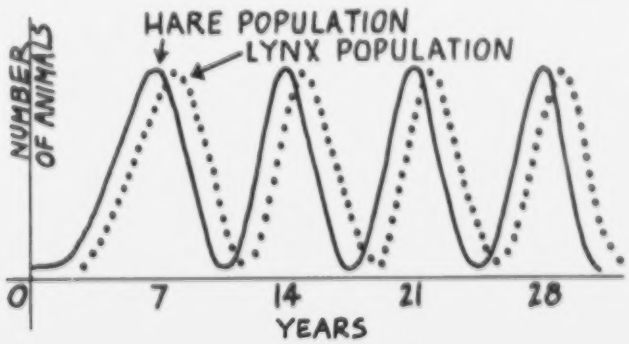
EXTENSIONS: 1. When you have finished tabulating the graph data and discussing it, ask the students if they have ever heard of the Hudson Bay trappers in American history. Tell them, briefly, who they were.

2. There is a hundred years, or more, of records of the activities of these trappers. In those records are some interesting data. These data refer to pelts shipped from America to Europe, particularly the pelts of snowshoe hares and lynx.

3. Researchers have found that snowshoe hare populations seem to peak about every seven to nine years and then crash, repeating the process over each comparable time period. So, a snowshoe hare population graph would look like this:

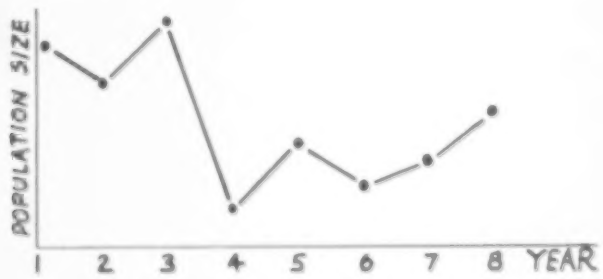


4. It has also been discovered that lynx populations do the same thing--except that they do it one year behind the hare populations. The combined graph would look like this:



Graph this right over the deer graph that you made, adding first the hares, and then the lynx. Ask the students:
Which animal is predator? Which prey?
Are predators controlling the prey, or are prey controlling the predators? (We have been brought up to "know" that predators control the prey--and are now discovering that this is not so. The number of prey animals available tells us how many predators can live in the area.)
Is this like the deer habitat game we just played? Who controls? (Sometimes the habitat--when the deer population is not too large; sometimes the habitat--when the deer population "gets on top of it" and destroys the vegetative food and cover.)
Some recent research has added a new dimension to the story of the snowshoe hares and the lynx.
It has been found that the major food of the hare is a small willow. As hare populations grow, the use of the willow plants grows too. But, when the willow plant has been "hedged" or eaten back so far, the plant generates a toxin (poison) which precludes use by the hare. That is when hare populations crashes, followed by the crash of the lynx population about a year later. Then the willow, relieved of pressure, begins to grow again. The hare population begins to grow in response, and last of all, within a year or so, the lynx population follows. And the cycle has begun again--over and over--every seven to nine years.

EVALUATION: 1. Name three essential components of habitat.
2. Define "limiting factors." Give three examples.
3. Examine the graph. What factors may have caused the following population changes:
a. between years 1 and 2?
b. between years 3 and 4?
c. between years 5 and 6?
d. between years 7 and 8?



Which of the following graphs represents the more typically balanced population?

Grades:	4-12
Subjects:	Science, Math, Social Studies, Physical Education
Skills:	Analysis, Application, Computation, Discussion, Problem Solving, Reporting, Graphing
Group size:	15 and larger
Key Vocabulary:	Habitat, limiting factor

MITIGATING CIRCUMSTANCES

OBJECTIVES: Students will become aware of interrelationships of the news media, politics, public opinion, and resource management conflicts.

CONCEPTS AND UNDERSTANDING: Animal Life Concept No. 4 - Animal resources can be managed and conserved. Understanding B - Certain local, state and federal agencies are charged with the management of animal resources. Understanding D - Animal Management programs are based upon both socio-political considerations as well as biological. Understanding E - Ethical actions involving animal life are the responsibility of society, but must start with the individual.

METHOD: - Students follow current news items which involve natural resource issues that focus on conflicts and developments.

BACKGROUND: Concept 4 A-B-C-D, 5-A, D, E.

Many controversial animal issue decisions are greatly swayed by public opinion, news coverage, or political pressure. In some situations, a conflict may be resolved based more on public opinion or political pressure than on sound biological information. In other cases conflicts arise between the need for power or energy and the habitat needs of a particular plant or animal. The Central Arizona Project will provide needed water to Central and Southern Arizona. Much work has been done to attempt to mitigate (lessen) the negative effects the canal may have on wildlife populations. Escape ladders have been built to help animals such as deer get out of the canal if they fall in. Underpasses have also been constructed to allow animals to move back and forth across the canal where migration paths would traditionally take them. Natural resource conflicts often involve decisions that bring into play politics, public pressure, the need for resources versus the desire to protect an animal population or its habitat. Much of wildlife management today involves the mitigation of the effects of man's project or needs on wildlife populations.

MATERIALS: Access to newspaper or television news.

PROCEDURE: 1. Discuss with the students the responsibility of both agencies and individuals towards managing wildlife and other resources.
2. Ask students to follow either a local or national news item that involves animals. Students in upper grades may wish to follow a piece of legislation through either a state or national level. It may be necessary to put students into groups or help them select a topic.
3. Have the students keep track of the issue by keeping news clippings and notes of television broadcasts.
4. Ask each student or group to present the controversy to the class. It is necessary for students to present both sides of an issue clearly. Some research may be necessary.
5. As a group brainstorm possible solutions or mitigations that especially attempt to minimize impacts on animal populations.

EXTENSIONS: 1. Have students debate a particular issue and then try to develop a comprehensive solution.
2. Have each group write up their controversy as a dilemma with several possible solutions.
3. Divide the students into groups and have each group research a regulation or news story concerning domestic animals. An example of this might be leash laws or the control of harmful insects with pesticide.

EVALUATIONS:

Grades:	7-12
Subjects:	Science, Social Studies, Language Arts
Skills:	Analysis, Application, Comparing Similarities and Differences, Description, Discussion, Evaluation, Research, Writing
Group Size:	Variable
Key Vocabulary:	Mitigation

ADAPTED FROM: "THE BEAUTIFUL BASICS", (PROJECT WILD)
WESTERN REGIONAL ENVIRONMENTAL EDUCATION COUNCIL, 1983

OBJECTIVE: Students will be able to identify basic needs of both wild and domestic animals.

CONCEPTS AND UNDERSTANDINGS: Animal Life Concept No. 1 - Animals are dependent upon their habitat for existence. Understanding B - the five essentials of animal habitat necessary to all species are: food, water, shelter, space or territory and the arrangement of these elements in relationship to each other.

METHODS: Students use their imagination to "become" their favorite animal and identify its habitat needs. They then list and organize basic needs of different animals.

BACKGROUND: Refer to Animal Life Introduction, Concept No. 1, Understanding B, and Animal Life Concept No. 2, Understanding A.

MATERIALS: Chalkboard

PROCEDURE: 1. Ask each student to pick their favorite animal. This can be either a domestic animal or pet or a wild animal. Ask each student to close their eyes and become that animal. Have the students visualize what they would see, hear, feel, or smell as that animal in its habitat.
2. After about 30 seconds, have the students open their eyes and write down three things that they visualized in their animal's habitat.
3. Using the chalkboard, list the animals the students chose. In another area, list what the students visualized while pretending to be their animal.
4. Discuss the list of animals with the students. Are some domestic and some wild? Did they visualize some of the same basic habitat components (food, water, shelter) for both domestic and wild animals? Ask the students to try and group the list of what they visualized into groups with headings of food, water, shelter, space, soil, sunlight and air. Discuss the idea that all animals need these basic components in their habitat, even though the specifics may differ. End the discussion by asking the students if people also needed these same basic components.

CONCLUSION: All animals require the same basic things to survive (food, water, shelter). Domestic animals, wild animals, and even people require these same basic components.

EXTENSIONS: 1. Have the students draw their animal in its habitat, making sure to provide the animal with all its basic needs.

EVALUATION: List at least four things plants and animals need for survival.

Which of these are needed by animals but not by plants: soil, water, air, food, shelter, arrangement, sunlight?

Grades:	2 to 12
Subjects:	Science, Language, Arts, Health
Skills:	Analysis, Comparing Similarities and Differences, Description, Drawing, Observation, Writing.
Group Size:	Any
Key Vocabulary:	Habitat, Wild, Domestic

PRECIOUS PRECIPITATION

Adapted from RAINFALL AND THE FOREST (Project Wild)

(c) Western Regional Environmental Education Council, 1983

OBJECTIVES: Participants will be able to: 1) visualize the different precipitation zones in Arizona, 2) understand what causes the differences in precipitation, 3) discuss what causes precipitation, 4) correlate precipitation to vegetative communities and animal life, and 5) understand how the location of cities is based on water supplies.

CONCEPTS AND UNDERSTANDINGS: Water 2A - Water is distributed and renewed through a water cycle. Water 3A - Precipitation varies from place to place. Water 3C - Humans redistribute the surface and subsurface waste. Water 5 - Water affects and is affected by nature and humans.

METHOD: Students work with a state highway map and a list of precipitation amounts for various communities in Arizona to map the precipitation zones in the state and compare this to the topography and vegetative communities.

BACKGROUND: Arizona is a diverse state with unique geographical features both within the state and in the surrounding region that impact directly on the distribution of precipitation around the state. In order to carry out this activity, the teacher should be familiar with Arizona's and California's general topographic features and how they influence the air movement into and across our state. You should also be acquainted with the water cycle and some of the major causes of precipitation in the atmosphere. A small, three-dimensional topographic map of Arizona, available from several map stores, would be helpful.

MATERIALS: One highway map of Arizona for each group of three or four students, one sheet of tracing paper about 17" x 22" for each group, four crayons of different colors per group, attached precipitation and elevation list for cities around the state, a copy of the state vegetative map for each group.

PROCEDURE: 1. Discuss the concept of interrelatedness with your students - the idea that all things, living and nonliving, are connected.
2. Divide your students into teams of three or four. Give each group a highway map and one sheet of tracing paper and one set of four crayons. Also provide each group with a copy of the list showing various communities and their precipitation and elevation.
3. Ask the students to outline the state on the tracing paper with their crayons.
4. Have them separate the list of communities into four precipitation zones, 0 to 5 inches, 5.1 to 10 inches, 10.1 to 15 inches, and 15.1 or more inches.
5. Assign a color for each precipitation zone and have the students mark a large dot (about the size of a dime) of the appropriate color at each community's location on the tracing paper.
6. Draw lines between dots of different colors (not from dot to dot) to create a separation between areas of different amounts of precipitation. Color each area with the appropriate color.
7. Discuss precipitation in the state: Where does the rain and snow come from? What influences the patterns of precipitation in the state? Does elevation influence precipitation amounts or whether it is rain or snow? (Compare Payson and Winslow.) What is a rain shadow? How does the topography influence the different amounts of precipitation?
8. Give each group a vegetative map of the state and have them overlay their precipitation maps on it. Compare the two and have them draw conclusions as to how the precipitation affects the vegetation.

EXTENSIONS: 1. Obtain a set of climatic maps from the Arizona State Climatologist and compare them to your maps. Discuss why southeastern Arizona gets most of its moisture in the summer, while northwestern Arizona gets its in the winter. How does this affect the vegetation?
2. Obtain habitat maps of several animals in Arizona and compare these to your other maps.
3. Using the state highway map and fact sheets showing the communities you located, add the population of these communities to the fact sheet. Why are these communities located where they are? Does precipitation influence this?

EVALUATION: Write an essay describing the importance of precipitation on living things.

Grades:	5 to 12
Subjects:	Geography, Language, Arizona History, Science
Skills:	Anaysis, Comparing Similarities and Differences, Discussion, Evaluation, Generalization, Mapping, Small Group Work, Writing, Drawing Conclusions
Group Size:	10 to 35
Key Vocabulary:	precipitation, climate, habitat, topography

ANNUAL RAINFALL FOR ARIZONA CITIES

Cities	Average Precipitation (inches)	Elevation (feet)
Ajo	9.1	1,736
Alpine	20.73	8,000
Casa Grande	8.20	1,405
Clifton	12.54	3,465
Douglas	12.25	4,020
Flagstaff	20.23	6,993
Fredonia	9.9	4,675
Gila Bend	5.69	737
Globe	15.75	3,540
Grand Canyon	15.81	6,965
Holbrook	8.64	5,061
Jacob Lake	18.52	7,920
Kingman	10.63	3,345
McNary	24.70	7,320
Nogales	15.60	3,800
Parker	4.83	425
Payson	21.48	4,910
Phoenix	7.46	1,117
Pinedale	18.69	6,500
Safford	8.95	2,900
Sedona	17.12	4,223
Show Low	15.35	6,400
Springerville	12.11	6,964
Tombstone	13.79	4,610
Topock	4.8	450
Tuba City	6.83	5,936
Tucson	11.1	2,410
Wickenburg	10.99	2,070
Wickieup	10.79	2,125
Willcox	11.76	4,200
Williams	21.88	6,750
Winslow	7.34	4,880
Yuma	3.38	138

SOURCES: Mammal Maps - Recent Mammals of Arizona, Lendal Cockrum, U. of A. Press
Vegetative Map-Agric. Experiment Station, U. of A., Tucson 85721
Bulletin A-45 (Map)

Adapted from: "Deadly Links" (Project Wild)
(c) Western Regional Environmental Education Council, 1983

OBJECTIVES: Students will be able to: 1) give examples of ways in which pesticides enter food chains; and 2) describe possible consequences of pesticides entering food chains.

CONCEPTS AND UNDERSTANDINGS: Animal Life No. 1 - Animals are dependent upon their habitat for existence. Understanding D - Animal species and their numbers are affected by changes in the quality and quantity of their habitat.
Animal Life No. 2 - Animal species are interdependent with one another and with their environments. Understanding B - Living things are interrelated through food chains and food webs. Understanding D - Animals can be a barometer of environmental quality.
Animal Life No. 5 - Animals are of value to men in many ways. Understanding D - The study of animal needs and behavior can give us insight into some of our own important needs and behavior. Understanding E - Animals have social, political, scientific, and ecological values.

METHOD: Students become "hawks," "shrews," "grasshoppers" in a highly-involving physical activity.

BACKGROUND: Refer to Animal Life Concept No. 1, Understanding D, Concept 2, Understandings A, B, and D. People have developed pesticides to control organisms. Herbicides are used to control unwanted plants; insecticides to control unwanted insects, etc. When these pesticides involve use of poisons, the poisons frequently end up going where they are not wanted. Many toxic chemicals have a way of persisting in the environment, and often get concentrated in unexpected and undersirable places--from food and water supplies to wildlife and people, too. For example, a pesticide (a chemical--frequently synthesized from inorganic compounds--used to kill something identified as a "pest" under some conditions) called DDT used to be applied regularly to crops as a means of controlling insects that were damaging the plants or trees. Then it was discovered that DDT entered the food chain with damaging results. For example, fish ate insects that were sprayed by the chemical; hawks, eagles, and pelicans ate the fish. The poisons became concentrated in the birds--sometimes weakening and killing them directly, and over time, resulting in side effects like eggshells so thin that the eggs would not hatch, or were crushed by the parents in the nesting process. The impact on species, including the bald eagle and the brown pelican, has been well documented. Use of DDT has now been prohibited by law in the United States; however, at least one temporary waiver was granted in recent years to allow its limited use. It has not been prohibited worldwide, and therefore still enters the food chain.

MATERIALS: White pipe cleaners and colored pipe cleaners (two-thirds white, one-third colored); or white paper dots and colored paper dots (same proportion as above): or any other materials (two-thirds white, one-third colored) that can be picked up by students easily; 30 of these items per each student is recommended; one paper bag per grasshopper.

PROCEDURE: 1. Tell the students that this is an activity about "food chains". If they are not familiar with the term, spend time in establishing a definition. (Food chain: a sequence or "chain" of living things in a community, based on one member of community eating the member above it, and so forth; e.g., grasshoppers eat plants like corn, shrews or other rodents eat grasshoppers, hawks eat rodents.)

2. Divide the students into three groups. In a class of 26 students, there would be two "hawks," six "shrews", and 18 "grasshoppers". (Work with approximately three times as many shrews as hawks, and three times as many grasshoppers as shrews.) Optional: Have grasshoppers, hawks, and shrews labeled so they can easily be identified; e.g., arm ties for grasshoppers, red bandannas for "red-tailed hawks" and brown arm ties for shrews.
3. Hand each "Grasshopper" a small paper bag or other small container. The container is to represent the "stomach" of whatever animal is holding it.
4. With the students' eyes closed, or otherwise not watching where you place the "food", distribute the white and colored paper dots (or whatever material you use) around in a large open space. Outside on a playing field if it is not windy or on a gymnasium floor will work; a classroom will also work if chairs and tables or desks can be moved back.
5. Give the students their instructions. The grasshoppers are the first to go looking for food. The hawks and shrews are to sit quietly on the sidelines watching the grasshoppers; after all, the hawks and shrews are predators, and are watching their prey! At a given signal, the grasshoppers are allowed to enter the area to collect food and place the food in their stomachs (the bags). The grasshoppers have to move quickly to gather food. At the end of 30 seconds, the grasshoppers are to stop collecting food.
6. The shrews are now allowed to hunt the grasshoppers. The hawks are still on the sidelines quietly watching the activity. The amount of time available to the shrews to hunt grasshoppers should take into account the size area you are working in. In a classroom, 15 seconds may be enough time; on a large playing field 60 seconds may be better. Each shrew should have time to catch one or more grasshoppers. Any grasshopper caught by a shrew--that is, tagged or touched by the shrew, must give its bag of food to the shrew and then sit on the sidelines.
7. The next time period (from 15 to 60 seconds, or whatever time you set) is time for the hawks to hunt for food. The same rules follow. Any shrews still alive may hunt for grasshoppers; grasshoppers are hunting for the food chips that represent corn or other plants; and the hawks are hunting for the shrews. If a hawk catches a shrew, the hawk gets the food bag and the shrew goes to the sidelines. At the end of the designated time period, ask all the students to come together in a circle, bringing whatever food bags they have with them.
8. Ask the students who are "dead", having been consumed, to identify what animal they are and what animal ate them. (If they are wearing labels, this will be obvious.) Next ask the hawks to empty their food bags out onto the floor or on a piece of paper where they can count the number of food pieces they have. They should count the total number of white food pieces and the total number of multi-colored food pieces they have in their food sacks. List any grasshoppers and the total number of white and multicolored food pieces each has; list the number of shrews left and the number of white and multi-colored pieces each has; and finally, list the two hawks and the number of white and multicolored food pieces each has.
9. Inform the students that there is something called a "pesticide" in the environment. This pesticide was sprayed on the crop the grasshoppers were eating, in order to prevent a lot of damage by the grasshoppers. If there was a lot of crop damage by the grasshoppers, the farmers would have less of their crop to sell, and some people and domestic livestock might have less of that kind of food to eat--or it might cost more to buy it because a smaller quantity was available. This particular pesticide is one that is poisonous, accumulates in food chains, and stays in the environment for a long time. In this activity, all of the multicolored food pieces represent the pesticide. All of the grasshoppers that were not eaten by shrews may now be considered dead, if they have any multicolored food pieces in their food supply. Any shrews for which half of more of their food supply was multicolored pieces would also be considered dead. The one hawk with the highest number of multicolored food pieces will not die at this time; however, it has accumulated so much of the pesticide in its body that the eggshells produced by it and its mate during the next nesting season will be so thin that the eggs will not hatch successfully. The other hawks are not visibly affected at this time.

10. Talk with the students about what they just experienced in the activity. Ask them for their observations about how the food chain seems to work, and how toxic substances can enter the food chain with a variety of results. The students may be able to give examples beyond those of the grasshopper-shrew-hawk affected by the pesticide in this activity.

CONCLUSION: Some pesticides such as DDT may be concentrated through a food chain and persist in the environment for long periods of time. Animals such as fish-eating birds, raptors, and even people concentrate the chemical in their bodies over a period of time.

EXTENSIONS: Consider and discuss possible reasons for use of such chemicals. What are some of the trade-offs? What are some of the consequences?

EVALUATION: Give three examples of ways in which pesticides could enter a food chain.

Grade:	4-9
Subjects:	Social Studies, Science, Physical Education
Skills:	Application, Classification, Description, Generalization, Making Inferences, Listening, Synthesis
Group Size:	Minimum of ten students
Key Vocabulary:	Pesticide, Food Chain

zbha300

"I'M HUNGRY!"

OBJECTIVES: Participants will be able to: 1) understand the source of their food supplies; 2) describe the natural resources required to produce the food and get it to their homes; and 3) discuss the changes which have been made in our ability to produce and store food.

CONCEPTS AND UNDERSTANDINGS: Humans in the Environment: HE 1A - Like other living things, we depend upon the biosphere for the basic requirements of life; HE 2C - We feed and clothe the world's population by increasing the production of selected plants and animals; HE 2D - We produce many of today's "necessities" for life from things geologic and water; HE 2E - The availability and distribution of renewable and nonrenewable resources influence our lives; HE 3A - We interrupt some cycles or food chains; HE 3B - We transfer resources from one place to another; HE 3D - The quality and quantity of resources change as natural cycles are modified; HE 4A - New technology increases our ability to make changes.

METHOD: Participants will develop a menu for a meal and trace its production, using research and reporting techniques.

BACKGROUND: Any or all of the Concepts and Understandings listed above may be used to discuss various steps or findings in this activity. This information is found in the Humans in the Environment Chapter on several pages. Resource information for completing this activity may be gathered from local agricultural commodity groups, such as the cattle growers or vegetable producers, the Cooperative Extension Service, the Arizona Farm Bureau, and local offices of the U.S. Department of Agriculture. The amount of work and research done on this activity could be adapted to the grade level you are teaching.

MATERIALS: A chalkboard and curious minds.

PROCEDURES: 1) Plan a dinner for an average family, including the items to be served and the amount of each item.

2) Have each student or a team of students, if there are not enough items, select one item from the menu and do the following:

A. Find out where the food item may have been grown. If grown in several locations, determine which location provides that food item to Arizona during which months of the year. Plot these locations on a map of the world or the United States.

B. Trace the path that the food item took from one of the places it was grown to your home.

C. Find out how much water was needed to produce the food item. Where did the water come from - rain or snow that fell on the field, or from irrigation? If irrigation was used, was the water diverted from a river, or was it pumped from the groundwater?

D. If the food item came from a plant or animal, trace the history of that kind of plant or animal during the last 200 years. Has man changed or bred it to increase the production?

3) Give reports and summarize the above items for the total meal.

4) Can we reduce the amount of water used in supplying these food items?

5) How would this meal have been different for someone living or traveling in or near your community 100, 200, or 500 years ago?

6) Place the food items into one of the categories shown on the pyramid on page ____ of the Human in the Environmental Chapter.

7) What role did things geologic, air, and sun play in producing these items?

EXTENSIONS: 1) Based on the information discovered in this activity, discuss how it confirms any of the understandings listed in the Concepts and Understandings in this activity.
2) Do a similar kind of activity for a set of clothing that one of the students might wear to school.
3) Make a large map of the United States and record on it all the places one of your food or clothing items might have been before it reached your community.
4) Try to determine how many people were involved in growing and delivering the item to your home.
5) In addition to the water used in growing and processing the item, how else was water and things geologic used to provide that item for your use?
6) How would the use of water and things geologic change if you had grown the item yourself?

EVALUATION: Compare the meal you developed to the meal a family in another country might have.

Grades: K-12, adapted to the group

Subjects: Language Arts, Science, Social Studies, Art, History

Skills: Analysis, Application, Computation, Description, Discussion, Evaluation, Generalization, Making Inferences, Mapping, Problem-Solving, Reporting, Research.

Group Size: Up to 30

Key Vocabulary:

MOON TRIPS

OBJECTIVES: Participants will be able to: 1) describe what resources would be needed to take a trip to the moon; 2) discuss and list the various decisions required to undertake an effort of this nature; and 3) understand the impact of such a decision on our biosphere.

CONCEPTS AND UNDERSTANDINGS: Humans in the Environment: HE 1A - Like other living things, we depend upon the biosphere for the basic requirements of life; HE 1C - We live at the top of a pyramid as part of the animal kingdom; HE 2B - Many humans reside and work in fabricated environments; HE 2D - We produce many of today's "necessities" for life from things geologic and water; HE 3B - We transfer resources from one place to another; HE 3C - We introduce waste products into local natural cycles; HE 4A - New technology increases our ability to make changes; HE 4C - Economic and social decisions often affect the environment.

METHOD: Participants will plan a trip to the moon and list how the materials they use to make the trip are gathered from the environment. They will relate these materials to the basic resources needed to support life.

BACKGROUND: Any of the understandings listed above may be used to discuss and evaluate the impact of such an undertaking on the environment. Information on these Concepts and Understandings is found in the Humans in the Environment Chapter. This activity will probably take several weeks to complete, and after the initial planning, you may wish to only devote 30 minutes once a week to reporting on progress.

MATERIALS: A map of the world and reference material which may be in your library or may need to be gathered.

PROCEDURE: 1) List all the things that you might need to take a trip to the moon.
2) Using the broad categories of Air, Water, Food, Shelter, Space, and Energy, place the items from your list into the appropriate category. (If you have not already done so, you might compare these categories to those found on page ____ of the Animal Chapter.
3) Review your list and add any items that are missing. Don't forget to include a rocket and power to get you up and down and the ship itself.
4) Have each student take one of the items listed in your final list and find out what natural resources are used to produce it and carry it on the ship.
5) On a map of the world, identify the geographic area from which the raw materials (natural resources) were produced.
6) Discover what happened to the item from your list after it was used and what happened to the material it was carried in. Was it recycled in space, dumped in space, or brought back to earth to be reused or discarded?
7) Find out if the same kinds of items were used by the last NASA flight as your trip to the moon and, if not, what change occurred. Why did it change? How did technology cause this change?
8) Mark out an area in the classroom or on the schoolground that represents the basic size of your spaceship. How will you get all your gear inside? How long would you like to live in this area? How long can you live here with the items you are taking?
9) Using the categories found on the pyramid on page ____ in the Humans in the Environment Chapter, decide which category each of the items you are going to take comes from. What would happen if the plant layer or the water circle was gone? Could we take the trip? Could we live right where we are?
10) How many of the items we take with us can be replaced by things we will find in space? This is based on current knowledge, not guessing.

11) How many people will it take to provide all the materials and support needed to get you to the moon and back?
12) Was the trip worthwhile? Vote on this, letting each student cast a vote. If some say "yes" and some "no", have a debate on the pros and cons of the issue.

EXTENSIONS: 1) Plan a trip from your home community to another community in Arizona using the same process.
2) Plan a trip from home to some place not on the North American continent using the same process.
3) Plan to take a horse or some other large animal on one of your trips. Is it easier to plan for this animal than for a human? Why or why not?
4) Discuss what would happen if one of the items you needed came from another country and they were not friendly to the United States. Could we go? How could we get around this problem?

EVALUATION: Write a story on a trip to a favorite spot and describe what you will use and take with you.

Grades:	K-12, adapted as needed
Subjects:	Language Arts, Arithmetic, Geography, Science
Skills:	Analysis, Application, Computation, Description, Discussion, Evaluation, Generalization, Making Inferences, Mapping, Problem-Solving.
Group Size:	Any
Key Vocabulary:	

LIFE STYLES

OBJECTIVES: Participants will be able to: 1) understand the different biotic communities found in Arizona, 2) discuss how humans live in some of these areas, 3) compare differences and similarities between the life styles for people in each area.

CONCEPTS AND UNDERSTANDING: Humans in the Environment (HE) 1B - The biosphere includes many environments in which humans live, HE 2A - The local environment has an impact on the local human population, HE 2B - Many humans reside and work in fabricated environments, HE 2D - We produce many of today's "necessities" for life from things geologic and water, HE 2E - The availability and distribution of renewable and nonrenewable resources influence our lives, HE 3A - We interrupt some cycles or food chains, HE 3B - We transfer resources from one place to another, HE 4B - Population growth creates more demands, HE 4C - Economic and social decisions often affect the environment, HE 5A - The environment is complex and interrelated, HE 5B -We need to recognize our impact on the environment and accept it, HE 5C - We can plan for wiser use of natural resources and reduce our impact.

METHOD: Participants will compare the living conditions for humans in several towns or cities and the impact of our occupancy on the native plants and animals through a research project. The amount of research will depend on the age of the class.

BACKGROUND: Each of the Concepts and Understandings listed above may be used as a basis for discussion as this activity progresses. Information about these are found in the Humans in the Environment chapter. Additional information can be found in several of the other chapters in this guide. A good way of handling this activity might be to trade information with a class in one of the other towns or cities you select to study.

MATERIALS: If you decide to trade information with a class in another city, you will need a shoe box or two in which to send your items to them. You will also need a camera and a collecting trip to get the materials you will trade.

PROCEDURE: 1. Using the list of Primary Biotic Communities of Arizona found on pages ____ of the Plant Chapter, select at least three Arizona towns or cities. Each of these human communities should be located in a different biotic community.

2. Divide the class into groups and let each group research the following things about their assigned or selected town or city. This can be done strictly through library work and contacting a local Chamber of Commerce or by trading as suggested under Materials.

A. What are the plants like in and around the city? Include both native and landscape plants.

B. What kind of animals (wild and domestic) are found within 10 miles of the center of the city or town?

C. What are the basic materials used in building homes - wood, block, amount of insulation, etc.?

D. How big is the city or town - population, square miles or acres, etc.?

E. What are three of the primary businesses that support the city?

F. Where does the city get its water and how is this water used by an average household?

G. Are there any pollution problems in the area?

H. Where does the city get its electricity - trace to power plant?

I. How does the use of electricity or natural gas vary from month to month in an average household?

J. When was the city first settled and why did people settle here?

K. What has been the yearly or 5-year changes in population from the settlement date until today?
L. Will water be a limiting factor in future growth?
M. Will some other natural resource be a limiting factor in growth of the area?

3. Have each group develop and give a report on their selected city or town.
4. Compare the items researched in item 2 between the selected cities or towns.
5. Select an item used in building homes that is common to all the cities or towns and trace it back to its origin. List all the steps it took to get from the original, natural resource to the finished home.
6. Compare today's city or town to the villages or lifestyles of people who lived in the same area 100, 200 and 500 years ago.
7. Project some possible changes that may take place in these human communities 10, 25, and 50 years from now. How would each group control future changes and why?
8. What kind of changes have occurred in the plant and animal life of the area during the last 200 years? What might happen to them in the next 25 years? Why?

EXTENSIONS: 1. Use any of the understandings listed above to discuss some of these findings in more detail.
2. Correspond with the city or county planning and zoning board in one of your selected places to find out what their concerns are and how they are attempting to deal with them.
3. Compare the reason why people originally settled in one of these communities to why they now go there to live. Is it the same reason or has some other factor become important? Does it have to do with the natural resources of the area?
4. Followup on questions this activity may have raised about your own city or town by visiting with local officials.

EVALUATION: Make an exchange box of natural items found in your home community and trade them with a class in another state or biotic community.

Grades: K-12, can be adapted

Subjects: History, Social Studies, Art, Language Arts, Arithmetic

Skills: Analysis, Comparing Similarities and Differences, Description, Discussion, Evaluation, Generalization, Making Inferences, Problem Solving, Reporting, Research, Small Group Work.

Group Size: Any

Key Vocabulary:

GOVERNOR'S COMMISSION
ON ARIZONA ENVIRONMENT

FACT SHEET

Questions & Answers About

WATER RESOURCES

206 S. 17TH AVE. PHOENIX, ARIZONA 85007 ★ ROOM 181

ENVIRONMENTAL FACT SHEET: **WATER RESOURCES**

People, animals and plants all depend on water to survive. In fact, about 70% of the human body weight is water. An adequate water supply is not only necessary for life itself, but man's basic activities also require water. It is used to grow food we eat and produce most of our manufactured goods, like the clothing we wear. (For instance, a hamburger, fries and a cola requires 1,500 gallons for their production). Water is used to keep us clean and healthy and to dispose of waste materials. Electrical energy often uses water in its production. Oceans, lakes streams and pools provide recreation sites for many people. Most individuals in a modern urban city personally use over 100 gallons each day.

Water also plays an important role in our economy. The old saying, "Arizona grows where water flows" is true. For this reason, the distribution, use and conservation of water is often controversial.

In Arizona there is stiff competition for our limited water supplies. Farms, industries, mines, growing cities and individuals all want more water. The problem is that we are already using water faster than it can be replaced by rainfall. Since 1977, Arizonans have annually used about 2.5 million acre-feet (325,000 gallons in each acre-foot) more groundwater than is replenished by nature.

Currently, there are two types of water supplies available in Arizona -- groundwater and surface water. Beginning in 1985, the Central Arizona Project will provide a third source, an imported supply.

On the average, Arizona receives less than ten inches of rainfall each year. Surface water supplies, such as rivers, streams and lakes, vary a great deal across Arizona. Due to the scarcity and irregularity of precipitation within the state, storage reservoirs are necessary to convert erratic stream flows into useful supplies. Major reservoir systems are located on the Salt, Verde, Gila, Agua Fria and Colorado River systems. Most of the natural surface water in Arizona has been developed and with exception of those supplies which will be developed as part of the CAP, no additional major developments are planned.

More than 60% of the state's annual water use is supplied from groundwater resources, which are found beneath the earth's surface in natural reservoirs of water bearing sand and gravel called aquifers. Water can enter aquifers by percolating downward. This is called recharge or replenishment. Recharge to the aquifers throughout most of Arizona is relatively small, occurring mainly along mountain fronts and in normally dry stream beds. Most of the water stored in Arizona's aquifers was placed there over millions of years.

Pumping groundwater out of an aquifer in much of Arizona is very similar to mining oil; once it is pumped, it is gone forever. Groundwater mining, or overdraft, occurs when the amount of water withdrawn from an aquifer is greater than the amount replenished.

The Central Arizona Project will help solve the problem of dwindling groundwater resources and expanding need for additional water supplies. The estimated long-term water supply to the central Arizona area by CAP is 1.3 million acre-feet per year, or two-thirds the rate of overdraft in its service area. The final third of the overdraft must be eliminated through conservation, augmentation of supplies and careful management of all water resources, including effluent (treated wastewater).

Arizona's new groundwater law established a State Department of Water Resources, which is in charge of overall water management. The Department is responsible for eliminating the groundwater overdraft by the year 2025. This will be done mostly by Management Plans in the basins where the population centers are, and where the largest agricultural production occurs.

QUESTIONS AND ANSWERS: **WATER RESOURCES**

Q. HOW IS ARIZONA'S WATER USED?

A. On an annual basis, 85% of Arizona's water is used by agriculture, 8% by municipalities and industries, 4% by mining and the remaining 3% for power generation, recreation and fish and wildlife. It is clear that given Arizona's limited water resources, we have over expanded our agriculture economy.

Q. WHY IS IT BAD TO DEPLETE OR MINE GROUNDWATER?

A. Depleting our groundwater supplies can cause many problems, including land surface subsidence, poor quality water and increased pumping cost. Besides, all non-renewable natural resources should be protected and conserved.

Q. WHERE IS GROUNDWATER DEPLETION OCCURRING IN ARIZONA?

A. Depletion is occurring mainly in Maricopa, Pinal, Pima and Cochise Counties.

Q. WHAT IS BEING DONE TO AVOID DEPLETION OF THE STATE'S GROUNDWATER SUPPLIES?

A. In 1980, Arizona enacted a comprehensive groundwater management law. The law designated four areas of the state, called Active Management Areas, where significant groundwater depletion is occurring. These areas include 80% of the state's population and account for 70% of the overdraft. The Department of Water Resources must develop a series of management plans to require conservation in these areas.

Q. HOW CAN WE CONSERVE IN OUR HOMES?

A. There are two basic ways to conserve water: by changing your water use habits and by installing helpful devices. There are lots of habits that affect the way we use water. Some good water use habits are: turn the tap off while you brush your teeth, never use the toilet as a trash can, take shorter showers and never use a hose to sweep your driveway or patio. Conservation devices are available for sinks, toilets and showers that automatically reduce the amount of water you use. There are also ways to reduce the amount of water outdoor plants and lawns require; and to change your plants to beautiful low water and low maintenance varieties.

Q. HOW MUCH WATER DO WE USE IN OUR HOMES?

A. Depending on where you live in Arizona you probably use between 150-300 gallons of water at your home each day. Over half (55%) of the water used at home is placed outdoors to water lawns, plants, shrubs, and flowers. Inside the home most water use (75%) occurs in the bathroom. Everytime the toilet is flushed, 5-7 gallons of water goes down the drain. Most showers use 12 gallons of water every minute. If you take a ten minute shower you've used up 120 gallons of water!

Further information may be obtained from:

Southern Arizona Water Resources Association
465 West St. Mary's Road, Suite 100
Tucson, Arizona 85705
(602) 624-9000

and

Arizona Department of Water Resources
99 East Virginia Street
Phoenix, Arizona 85004
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GOVERNOR'S COMMISSION
ON ARIZONA ENVIRONMENT

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GOVERNOR'S COMMISSION
ON ARIZONA ENVIRONMENT

FACT SHEET

Questions & Answers About

WATER QUALITY

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ENVIRONMENTAL FACT SHEET: **WATER QUALITY**

Arizona's surface and groundwater quantity concerns are reflected in a 120-year history of selective settlement patterns, legal disputes, legislative issues and cooperative resource development programs. However, with increased competition for the limited quantities of water available in Arizona, quality issues have become increasingly important. The new groundwater code adopted in 1980 and the Arizona Water Pollution Control Act have provided the legal framework in establishing standards for water quality.

The true cost of pollution is an issue which not only affects today's citizens, but also significantly impacts the quality of life in Arizona for future generations. Many of the issues pertaining to water quality are economic in nature. Economic growth and development is beginning to strain the limits of our high-quality water supplies, and the economic competition among users for quality supplies will intensify. This will occur in an environment of steadily-rising costs for energy and new capital construction. Costs for water treatment, storage and transmission facilities will double and in some areas triple the amount consumers will have to pay for their water. Hence, the importance of preserving Arizona's resources in order to hold down costs is an increasingly important priority as the need for quality drinking water is balanced against the state's municipal, agricultural and industrial needs.

A significant development for the Bureau of Water Quality Control is an increased emphasis on the groundwater quality issues in Arizona. Traditionally, groundwater had been regarded as an unpolluted resource. However, the analytical techniques developed during the 1960's and 70's allowed the analysis of organic compounds in very small quantities (part per billion or less). The more sophisticated ability to isolate organic contaminants has resulted in identifying major groundwater contamination problems.

A current example of one of the organic chemicals found to be contaminating groundwater supplies in Arizona is trichlorethylene (TCE). TCE is a solvent for fats, waxes, resins, oils, rubbers, paints and varnishes with a multitude of uses. It is most commonly used as a degreaser in various industries. Other applications include dry cleaning, paint stripping, automotive body polishing and decaffeinating coffee. In sufficient concentration, TCE can be toxic and has been found to cause cancer in mice but not rats.

TCE is one of a class of 32 compounds identified as "purgeable organics," so named because of their volatility. There are 17 sites (including 113 wells) statewide which have been contaminated with purgeable organics. These compounds do not occur in nature, but are man-made and enter the environment because of improper disposal. Once in the groundwater supply, they do not degrade, but remain indefinitely. Despite the known toxicity and suspected carcinogenic nature of TCE, regulatory maximum contaminant levels in drinking water have not yet been established. The Arizona Department of Health Services has developed voluntary guidelines for TCE in response to requests from public water suppliers.

There are many widespread areas where TCE has been found in Arizona; four are: near the Tucson International Airport, in the northwest Tucson (Cortaro) area, in the Indian Bend Wash Area on the boundary between Tempe and Scottsdale, and at the Phoenix-Litchfield Municipal Airport in Goodyear. The Tucson International Airport, Indian Bend Wash and the Phoenix-Litchfield Airport sites have been designated as eligible for Superfund monies. Approximately 25 drinking water wells have been contaminated. Thirteen other non-potable supply wells have also been found to be contaminated with greater than five parts per billion TCE, and have been removed from service. Water supply monitoring is continuing in areas where industries associated with this type of pollution are located.

The best solution to prevent future TCE problems is the adequate disposal of wastes to ensure that groundwater contamination cannot occur. In Arizona, solvents such as TCE are now largely being recycled, regulations are in place for solid and hazardous waste disposal, and regulations are being developed for underground injection of wastes and for groundwater quality. However, underground storage of virgin solvents is not regulated and the tanks used for such storage often leak.

Water source contamination may be the "environmental threat of the 80's," not only in Arizona but across the country. It is a complex problem that has only recently been realized and is not yet fully understood. Each case is unique and cannot be clearly defined without extensive monitoring and the expenditure of significant resources. The Arizona Department of Health Services will continue to work with water purveyors, producers, users, industries and federal agencies to ensure a safe and adequate water supply for Arizona.

QUESTIONS AND ANSWERS: **WATER QUALITY**

Q. WHAT ARE THE SOURCES OF WATER IN ARIZONA?

A. Water becomes available to consumers from surface waters (example: Colorado River, Salt River, Verde River, Gila River) and/or groundwater sources (example: Upper Santa Cruz Basin, Salt River Valley Basin, Lower Santa Cruz Basin, Harquahala Basin and Irregation Non-expansion Area).

Q. HOW MANY WATER SYSTEMS ARE THERE IN ARIZONA?

A. Almost 1,500 water systems providing drinking water to the public are regulated through the Bureau of Water Quality programs. They serve 2.7 million of the state's population. The remaining systems are too small to monitor (fewer than 15 hook-ups and less than 25 people) or are private wells.

Q. WHAT IS PURE WATER?

A. All natural water has some impurities in it. If water meets the standards established by the Environmental Protection Agency and the Arizona Department of Health Services* as necessary for drinking, it is considered "pure."

Q. WHAT KIND OF THINGS POLLUTE WATER?

A. Minerals, mineral salts, nutrients, biological contaminants, and organic chemicals (solvents, pesticides, agricultural chemicals) are the most common forms of pollutants found in water.

Q. WHAT ARE THE MOST COMMON POLLUTANTS FOUND IN ARIZONA'S WATER?

A. The most common **naturally** pollutants are flourides, mineral salts and arsenic. The most frequent sources of **man-caused** contaminants are nitrates and organic chemicals (TCE, DBCP). During the next 20-30 years, organic chemicals will continue to be serious pollutants of Arizona's water. The potential danger is especially significant in light of the extensive development of new chemicals for agricultural and industrial uses. One of the greatest long-term pollutants to Arizona's groundwater resources is salt concentrations.

Q. WHERE DOES WATER POLLUTION OCCUR IN ARIZONA?

A. The major pollution problems are:

1. TCE in Tucson and Phoenix groundwater
2. DBCP contamination of groundwater in Phoenix and Yuma
3. Pinetop-Lakeside bacterial contamination
4. Mine waste near Globe-Miami and other areas
5. Nitrate levels in the St. David area
6. Recreational development in Arizona waters
7. Contamination from active and abandoned mines
8. Salinity in the Colorado River
9. Puerco River contamination from uranium mine tailings spill near Gallup
10. Soil erosion from land disturbance in open range and riparian areas
11. Eutrophication (oxygen deficiency resulting from high phosphate levels) of recreational lakes

Q. HOW IS POLLUTION IN WATER MEASURED?

A. Pollutants are measured on a volume per volume basis. The number of organisms per volume is analyzed against applicable standards for the intended use.

Q. HOW DO POLLUTANTS AFFECT OUR USE OF WATER?

A. Water standards are developed based on the planned use of the water. Certain minerals may make water good for drinking and bad for agriculture, or vice-versa. The use will determine the quality criteria..

Q. HOW DO WE MAKE WATER POTABLE?

A. Potable means that the water is acceptable for drinking. A number of treatment methods are available and the type of treatment is determined by what needs to be removed. Organics may be treated by activated carbon filtration. Bacterial problems would be treated by a form of disinfection, such as chlorination, spraying, or ultra-violet light.

Q. WHAT DOES IT COST TO MAKE WATER POTABLE?

A. The cost is determined by the kind of problem, type of hardware necessary, size of the facility, and quantity of water to be treated.

Q. WHAT DO WE DO WITH POLLUTED WATER?

A. The desired use of the water will determine a course of action. Water which is unacceptable for drinking may be used for agricultural purposes. Polluted water can be treated to attain compliance with drinking water standards or it can be blended with high quality water to dilute the concentration of pollutants.

*Available from: Northern Regional Office (Flagstaff/779-0313)
Southern Regional Office (Tucson/628-5321)
Central Regional Office (Phoenix/255-1258)

Further information may be obtained from:

Arizona Department of Health Services
Bureau of Water Quality Control
1740 West Adams
Phoenix, AZ 85007
(602) 255-1253

Department of Water Resources
99 E. Virginia
Phoenix, AZ 85004
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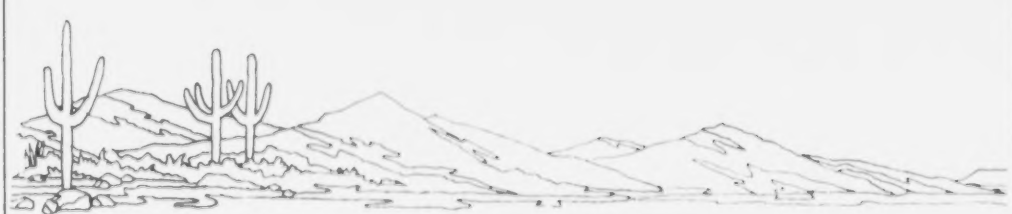

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GOVERNOR'S COMMISSION
ON ARIZONA ENVIRONMENT

FACT SHEET

Questions & Answers About

PLANTS

206 S. 17TH AVE. PHOENIX, ARIZONA 85007 ★ ROOM 181

ENVIRONMENTAL FACT SHEET: **PLANTS**

Arizona is one of the most topographically varied and scenic areas in North America. Arizona is characterized by a tremendous diversity of habitats. It is the fifth largest state in the U.S. with one area of about 113,900 square miles. The latitudinal and longitudinal range is great, the latitude extending from 31°20' to 37° N, and in longitude from 109° to almost 115° N. The altitudinal range is also great, from near sea level in the southwestern corner of Yuma County, to 12,600 feet at the summit of San Fransisco Mountains in Coconino County. Arizona's plant life is extremely varied as well, reflecting the diversity of topography, soils, and climate. Arizona has been described as a "meeting ground for a large number of floral types, representing those of nearly every part of North America. Alone among the states it has both alpine plants and plants of mainly tropical affinity in the Mexican boundary region" (Kearney, Peebles and collaborators, 1960). Over 4200 different kinds of plants are found in Arizona, ranking it fourth in total number of plant species in the United States, including Hawaii.

To help protect many of these diverse natural resources, Arizona enforces a strict Arizona Native Plant Protection Law.* This law prohibits the collection of many plants except under permit from the Arizona Commission of Agriculture and Horticulture. A permit may be granted if removal is for the purpose of education or science or if the plants are threatened by their location or a change in land usage. With this permit, written permission has been obtained from the land owner or his agent.

In Arizona nearly five percent of the total number of plant species are known only from within Arizona (Kearny, Peebles, and collaborators, 1960). Of the endemics, 46 species are confined to northern, 20 to central, and 74 to southern areas of Arizona. The remaining 16 species are more widely distributed in the state. Eleven species and two varieties are known only from within the borders of Grand Canyon National Park and its immediate vicinity. Reproductions of these plants takes some unique and complicated processes in nature which in the case of the Saguaro occurs on the average about every 25-30 years. (Growth of plants is generally extremely slow, owing to the predominately arid conditions.)

*Copies of the Native Plant Law are available from the Arizona Commission of Agriculture and Horticulture.

QUESTIONS AND ANSWERS: **PLANTS**

Q. HOW ARE PLANTS DISTRIBUTED IN ARIZONA?

A. The major terrestial communities, ecologically speaking, are based on the native perennial plants found there. These plants are ever present, sensitive and measurable indicators of the environmental influences of climate, soil, topography, and biotic factors, including man, that govern their distribution. In Arizona nine vegetation types are recognized:

Alpine (11,000 - 12,500 feet)
Northern Mesic Evergreen Forest (6,000 - 11,000 feet)
Western Xenic Evergreen Forest (4,000 - 7,000 feet)
Grassland (5,000 - 7,000 feet)
Desert Grassland Transition (4,000 - 6,000 feet)
Arizona Chaparral (4,000 - 6,500 feet)
Great Basin Microphyll Desert (3,000 - 3,500 feet)
Arizona Succulent Desert (3,000 - 3,500 feet)
California Microphyll Desert (below 3,000 feet)

Q. HOW MANY DIFFERENT KINDS OF NATIVE PLANTS ARE THERE IN ARIZONA?

A. Over ninety species of plants endemic (native) to Arizona and over 100 additional species described as nearly endemic (those which may be found with very limited occurence outside the state) are listed as sensitive, threatened, rare, or endangered by such agencies and organizations as the U.S. Fish and Wildlife Service, Forest Service, Bureau of Land Management, National Park Service, State of Arizona, and the Arizona National Heritage Program. Seven species are federally listed as endangered by the U.S. Fish and Wildlife Service. Approximately 40 plant classifications are proposed by the U.S. Fish and Wildlife Service for listing as threatened or endangered, pending further study.

Q. WHY ARE SOME OF THEM PROTECTED?

A. Over 200 species of plants are protected, some because of their rarity and others because they are desired commercially for landscaping and by the collectors whose actions would soon put them on the rare status.

Ecologists recognize that the accelerating destruction of natural habitats and the extinction of species is eliminating important opportunities for future biological research (Wilson, 1983). Hundreds of agricultural, medical, and industrial products have evolved from or owe their existence to plants.

Reproduction of these plants takes some unique complicated processes in nature which in the case of the Saguaro occurs on the average about every 25 - 30 years.

Q. HOW MANY DIFFERENT CROP PLANTS DO WE GROW?

A. In Arizona, thirteen major agronomic crops are grown:

Cotton - Upland and American
Alfalfa Hay
Wheat
Barley
Corn for grain
Sorghum for grain
Sugar beets
Potatoes
Citrus
Grapes
Apples
Pecans
Pistachios

And ten fresh market vegetable crops:

Lettuce
Dry onions
Green onions
Broccoli
Carrots
Cauliflower
Cantaloupe
Honeydew melons
Watermelons
Potatoes

There are many minor crops grown here, but these are the major crops in Arizona.

Q. HOW MANY OF THESE ARE NATIVE?

A. Of all the principle crops harvested, none are native to Arizona and none are adapted to arid regions such as that found in Arizona. In the desert environment there are two strong climatic factors - high insulation and low humidity (Gentry, 1981). Many plants cannot tolerate these conditions even with supplemental water via irrigation. With continuing pressure on our available water resources there is growing concern and interest for the development of crop plants tolerant and adapted to arid conditions. A significant number of plants native to Arizona show great potential as economically important plants: tepary beans, mesquite pods, amaranths, devil's claw seeds, and chia seeds have exceptional nutritional value, the roots of wild Rhubarb have medicinal and other values, and jojoba is being cultivated as an oilseed crop which can substitute for sperm whale oil and other oils used in cosmetics, high performance lubricants, linoleum, printing ink and varnishes.

Q. WHAT NON-NATIVE PLANTS DO WE USE? WHAT FOR?

A. The crops that are listed in question number five are food and fiber crops. The fiber crop is used in textiles and many other manufactured goods.
The food crops are consumed raw or processed for human consumption.

Q. WHY CAN'T PEOPLE BRING PLANTS INTO ARIZONA?

A. Plant quarantines were established by the Arizona crop Pest Law and regulated and enforced by the Arizona Commission of Agriculture and Horticulture for dangerous insect pests and diseases that would be detrimental to agriculture and horticultural crops of Arizona. These insect pests and diseases do not usually arrive in this area by themselves, but are transported by people with plants that are the hosts for these insects and diseases. That is why the plants are refused entry unless they have had prior inspections at origin or certified free of a surface pest in the case of fruit that can be visually examined.

The tourist or visitor who enters the state through the agricultural inspection stations who have quarantined plant, fruit or nuts, have three options as to their disposition:

1. If edible, to consume.
2. To ship back to State or origin.
3. To be destroyed by the quarantine officer at the time of inspection.

Further information may be obtained from:

Arizona Commission of Agriculture and Horticulture
1688 W. Adams
Phoenix, Arizona 85007
255-4373

and

Desert Botanical Gardens
1201 N. Calvin Parkway
Phoenix, Arizona 85008
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GOVERNOR'S COMMISSION
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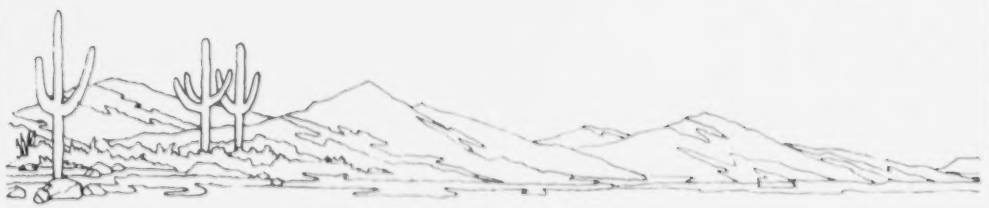
FACT SHEET

Questions & Answers About

WILDLIFE



206 S. 17th Ave. Phoenix, Arizona 85007 ★ Room 181

ENVIRONMENTAL FACT SHEET: **WILDLIFE**

What comes to mind when you think of wildlife? Is it that big elk you caught a glimpse of in a clearing along the road to Flagstaff; or that group of javelina you spotted on the way to Roosevelt Lake? While game animals such as these are probably the most readily identifiable wildlife for most Arizonans, they make up only a small fraction of the wildlife species in Arizona.

Arizonas natural diversity of wildlife and wildlife habitat is unique. More than 80 species of plants and animals are found nowhere else in the world. More than 120 other species regularly occur in Arizona but nowhere else in the world. Arizona Game and Fish Department has the legal responsibility to manage all the wildlife, game and non-game alike.

For us to assure the presence of this great resource, we must know about wildlife, its environments, or habitats. We must understand the interrelationships between species, between species and their environments, and the interrelationships between man and wildlife. We must understand and practice the concept of conservation. Conservation is the wise and careful use of a renewable resource. Conservation does not mean "putting up a fence" around a resource and giving it total protection. The harvest of lumber from a forest, or of forage from a grassland, shows us that such a harvest, properly controlled, does not damage a living renewable resource. Doesn't this concept also apply to wildlife, which is also a living, renewable resource?

We know the values of wildlife to man, not only as food and fiber, but as pollinators of domestic plants, as cleansers of the natural world, as sources of recreation, and as an inspiration for songs and legends, art, literature, and dance. History records conflict between man and wildlife; records of damage to man's crops, of hereditary fears of certain species, and of wildlife occupying lands desired and needed by man to feed the ever growing population. (How could America's farmers have lived with a hundred-million buffalo?)

Our knowledge of, our attitudes, and our relationships with wildlife are many faceted. Our attitudes have been affected by history, by economics, religious and ethnic backgrounds, and today are being dramatically affected by a conflict between urban and rural understandings of our natural world.

Today, Arizona is witnessing fantastic growth: massive construction projects, agricultural expansion, and an increasing use of land for homes, industry and recreation. Much of this has a dramatic, and far too often, detrimental effect on wildlife. But today, unlike in the past, there are knowledgeable, concerned people trying to alleviate and mitigate harm done to wildlife and its habitat.

Looking into the future, it is difficult to forsee anything but a continued deterioration of our environment and, in particular, a loss of wildlife habitat. As our human population occupies more of the land and utilizes more of its resources, we leave less land, less water, and less plant resources for our wildlife neighbors.

We must understand that in the years to come there will be less wildlife than now exists; and we must understand why. We must understand that if this occurs it is because we have made the decision that these lands must accomodate man first, and wildlife second. Let us be sure that such decisions are carefully considered for alternatives; and let us never accept the loss of any species. In our environment there must always be room for at least a remnant of each.

QUESTIONS AND ANSWERS: **WILDLIFE**

Q. HOW MANY DIFFERENT SPECIES OF ANIMALS LIVE IN ARIZONA?

A. 800 vertebrate species of wildlife live in Arizona; 65 fish, 27 amphibian, 97 reptile, 471 bird, and 140 mammalian species.

Q. HOW MANY ANIMALS ARE HUNTED?

A. Of the 800 species of vertebrates that occur in Arizona, only about 100 are currently hunted, trapped, or fished.

Q. ARE SOME ANIMALS ENDANGERED OR THREATENED . . .*

A. Animals such as Gila Topminnows (fish), Five-striped Sparrow and Elegant Trogons (birds) can be seen only in Arizona and are protected. At the present time, 102 species of wildlife are listed on the state's threatened Native Wildlife list. Only 20 are on the Federal Endangered and Threatened Species list.

. . . WHY?

Species habitat loss or alteration has had the greatest effect on population status.

Q. WHAT IS THE RELATIONSHIP OF A SPECIES AND ITS HABITAT?

A. The loss of a given wildlife species from a specific habitat causes a reduction in the stability of that ecosystem. This degradation of the environment caused by the removal of animal and plant life can, and does, have an adverse effect on the quality of the outdoors everytime. As it is commonly put "you can't do just one thing," or, for every action, there is an equal and opposite reaction. One notable example of this is the loss of cottonwood trees (in riparian areas of the State) that has totally altered the animal and plant life.

Q. WHAT IS MEANT BY WILDLIFE CONSERVATION?

A. The following five concepts, and their understanding contain the basic knowledge that is imperative for us all to have in reference to wildlife conservation and wildlife as part of our environment.

1. Wildlife is a product of its habitat.
2. Wildlife species are interdependent with one another and their environment.
3. Wildlife populations are not static, but are in constant change.
4. Wildlife is a renewable resource.
5. Man has been an important factor affecting plant and animal succession and other environmental processes.

The understanding of these concepts can assure the wise and careful use of wildlife as the renewable resource it represents.

*A complete listing of Arizona's Threatened Wildlife can be obtained from the Arizona Game and Fish Department.

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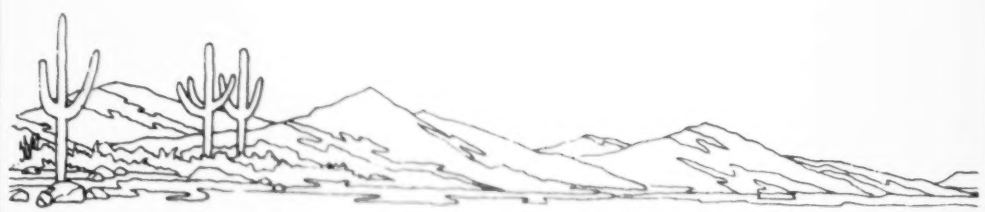
FACT SHEET

Questions & Answers About

AIR QUALITY



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ENVIRONMENTAL FACT SHEET: **AIR QUALITY**

Air is the mixture of gases that make up our atmosphere. When we speak of air, we are speaking of the troposphere - that air mass closest to the earth's crust.

Air is composed of a number of gases, water vapor and particulate matter, but it is the oxygen component that makes our planet livable. Without oxygen, no animal life, including man, can exist. This precious oxygen is found only in the first few thousand feet above us.

Natural processes continually recycle and renew important elements of our air. Carbon dioxide is absorbed by plants. The carbon is used for their needs and the oxygen is released into the atmosphere. Plants are the major producers of this most important resource, with oceanic plankton the greatest producers of oxygen. Atmospheric nitrogen is gathered from the air by certain bacteria, which transform it into nitrate compounds which plants can assimilate and use. Plant decomposition releases the nitrogen back into the atmosphere. Temperature, precipitation, and other factors influence the rate of renewal, and recycling of atmospheric elements.

Air, as we have seen, is a renewable resource and is essential to all living things. Each plant and animal requires specific quantities of air and uses particular elements of that air in its own way. But air can be contaminated by concentrations of its own elements, such as carbon dioxide, and by other natural or manmade materials.

Some air pollution is natural, as when a hot, dry wind blows across a droughty plain. At that time dust becomes a pollutant. Each of us is a source of pollution varying with time and place and activity. Industry is a major source of air pollution and towns and cities contribute to the deterioration of air quality. Agriculture produces certain contaminants, and our systems of transportation (cars, trucks, aircraft, ships, and trains) are the greatest single source of air pollution in today's world.

Air quality in Arizona is monitored in four areas every six days.

In Phoenix and Tucson air pollutants are of chief concern. Carbon monoxide, ozone, and particulates harm public health, impair visibility and soil clothing and other material. Carbon monoxide may be controlled by State emissions inspection of cars, expanded public transit, and the use of car pools to reduce emissions. Control measures for stationary sources of hydrocarbons are used to reduce ozone concentrations. Particulates are controlled by paving and curbing streets, stabilizing ground surfaces at construction sites and placing restrictions on the use of disturbed desert lands.

In copper smelter areas, sulfer dioxide and particulates adversely affect not only public health but vegetation materials and visibility. Particulates are also a problem in farming and industrial areas within the State's southern and western regions affected by copper smelters. Control equipment is being installed at some smelters to capture most of these emissions. In other smelters, first generation control equipment is used.

In the Central Mountain Region no air quality problems exist, except in winter when standards are exceeded due to residential and industrial wood burning.

QUESTIONS AND ANSWERS: **AIR QUALITY**

Q. WHAT ARE THE CAUSES OF AIR POLLUTION?

A. Air pollution is both natural and manmade. Natural pollution sources include dust storms and volcanoes. Manmade pollution is mainly caused from transportation and industry.

Q. WHAT ARE THE MAJOR AIR POLLUTANTS IN ARIZONA?

A. The air pollutants of chief concern are carbon monoxide, ozone, particulates and sulfer dioxide.

Q. WHAT ARE THE URBAN AIR POLLUTANTS?

A. Carbon monoxide, ozone and particulates.

Q. WHAT ARE THE SOURCES OF URBAN AIR POLLUTION?

A. The major source of urban air pollution is the automobile. Other man-caused contributing sources are power plants, fuel handling facilities, including cleaning operations. Finally, wind-blown dust.

Q. HOW DOES URBAN AIR POLLUTION AFFECT THE CITIES IN WHICH IT IS A PROBLEM?

A. There are health related problems with all pollutants. Excessive levels of carbon monoxide cause problems for those with cardiovascular ailments. Ozone and particulates cause respiratory problems, striking the most sensitive first. Finally, there are the aesthetic effects of particulates - no one likes to see the visibility obscured by brown "yuck".

Q. HOW CAN URBAN AIR POLLUTION BE CONTROLLED?

A. There are two contributing solutions:

1. Properly maintain vehicles so they emit the least amount of carbon monoxide, hydrocarbons and nitrogen oxides.

2. Reduce the amount of vehicle use; ride sharing and good trip planning reduce total miles travelled.

Q. HOW DOES CARBON MONOXIDE POLLUTE OUR ENVIRONMENT?

A. Air quality standards are exceeded due to emissions from motor vehicles, especially during winter months. Vehicular emissions are trapped at low levels at night when the atmosphere is stagnant due to temperature inversions. Federal new car emission standards, State emissions inspection of cars, expanded public transit, and car pool incentives are being utilized to reduce emissions.

Q. WHAT ARE PARTICULATES AND WHERE DO THEY OCCUR?

A. Air quality standards are exceeded in populated, industrial, and agricultural areas due to fugitive dust emissions from unpaved roads, construction work, disturbed desert land, tailings piles and agriculture. Control strategies to reduce concentrations are being developed.

Q. IS ARIZONA A HEALTHY ENVIRONMENT FOR PEOPLE WITH ALLERGIES?

A. It is important to realize that Arizona is not an "allergy-free haven", but has its own unique attributes with advantages and disadvantages for people with genetic predisposition to develop allergic reactions.

Q. WHAT TYPES OF POLLENS ARE FOUND IN ARIZONA?

A. The vast concentration of pollens occur in Phoenix Valley. The wide variety of pollens are grasses, trees and weeds. The most common grass is Bermuda which pollenates in March through November. Other grasses occur and are much less significant.

Further information may be obtained from:

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GLOSSARY

ABIOTIC - (Environment) - That part of the environment that is "without life".

ACCUMULATION - The gathering together of many soil particles to form a body of soil.

ADAPTATION - The evolution of features that made a group of organisms better suited to live and reproduce in their environment.

AEROBIC - In the presence of air.

AGRONOMY - The study and management of crops and soils for the production of food, fiber, and feed.

ALGAE - Simple one-celled plants containing chlorophyll. Must live in water.

ALLOMONE - A chemical produced by plants that repels or otherwise influences animal behavior, especially insects; as natural pesticide. (see pheromone)

ALPINE TUNDRA - A form of grassland with a layer of permafrost in the soil; found only on the highest peaks in Arizona.

ANAEROBIC - Without air.

ANIMAL HUSBANDRY - The care and management of domestic animals for production of food and fiber.

ANNUAL - A flowering plant that completes its life cycle in one growing season.

ANTHER - A part of the male stamen in the flower that produces pollen.

AQUATIC - (Habitat, plants) Waterbound.

ARABLE - Land so located that production of cultivated crops is economical and practical.

ATMOSPHERE - The gaseous envelope that surrounds the earth and penetrates accessible portions of the land.

AVAILABLE WATER CAPACITY - The capacity of soil to store (hold) water available for use by plants.

BASIN AND RANGE PROVINCE - A physiographic province in the western United States characterized by alternating mountains and valleys (constitutes all of Arizona south of the central mountain region).

BIENNUAL - A plant that requires two growing seasons for its life cycle - the first year being the vegetative growth and the second the sexual growth and death.

BIOLOGICAL CONTROL - Control of plants, animals and insects by another.

BIOSPHERE - The part of the earth's crust, waters and atmosphere where living organisms can subsist.

BIOTIC - (Environment) - That part of the environment which is "living", i.e., plants and animals.

BIOTIC COMMUNITY - Communities of plants and animals that can be recognized by patterns in the vegetation.

BOSQUE (boss-key) - Spanish word meaning forest or woods, usually referring to mesquite bosques in the Southwest.

BOTTOMLAND - Thick, fertile soil deposited by water movement from higher areas to low, depression areas and floodplains.

BROWSE PLANT - A woody plant that is selectively eaten; the new, green growth is browsed in the spring.

CACTI - A desert or transitional zone species, usually succulent, with spines.

CAPACITY - (See Carrying Capacity)

CARBOHYDRATES - A string of carbon atoms to which hydrogen and oxygen are attached in a 2:1 ratio; sugars, starches, cellulose mostly formed by green plants; a major class of animal foods.

CARBON CYCLE - (See Cycles) - The cycle of carbon in living beings in which carbon dioxide (CO_2) is fixed in plants by photosynthesis to form organic nutrients and is ultimately restored to the inorganic state by respiration (of animals), transpiration (of plants in the absence of sunlight), and the decay of organic matter.

CARRYING CAPACITY - The largest number of a species that can be maintained indefinitely in a given part of the environment, usually expressed as so many plants or animals per acre or square mile.

CHAPARRAL - (See Plant Communities interior chaparral, coastal chaparral) - Areas dominated by short trees and shrubs often spiny, with thick evergreen leaves.

CHLOROPHYLL - A green pigment of chloroplasts necessary for photosynthesis.

CHLOROPLASTS - An organelle in plants that is membranous and contains chlorophyll.

CIENEGA - Spanish word for marsh.

CLAY - Small particles of soil material that cannot be seen with a microscope and which feel sticky when wet.

CLIMATE - The average annual weather conditions, temperature, precipitation, and wind velocity, which determine the atmospheric environmental conditions of a given area; microclimate, macroclimate, or bioclimate.

CLIMAX - (See Succession) - The end stable state of ecological succession; i.e., climax grassland, forest or desert shrub.

COHESION - Holding together; force holding a solid or liquid together, owing to attraction between like molecules

COLORADO PLATEAU PROVINCE - A physiographic province in the western United States characterized by high elevation and relatively flat-lying sedimentary rocks (constitutes all of Arizona north of the Mogollon Rim).

COMPOST - A mixture of decaying organic materials, used to fertilize and condition soils.

CONIFEROUS - (See Plant Communities) - Cone bearing evergreen trees and shrubs.

CONSERVE - To use wisely in order to preserve the basic natural resource as opposed to exploitation.

CONSISTENCY - The degree of cohesion or adhesion of the soil mass.

CYCLES - (Carbon, energy, food, nutrient), hydrologic (water), life (natural), mineral, nitrogen, seasonal. A series of events that occur regularly (and naturally), and usually lead back to the starting point or original condition.

DECIDUOUS - Plants that lose their leaves in response to seasonal changes, such as wintertime or drought conditions.

DECOMPOSITION - The conservation of dead organic matter into nutrients by fungi or bacteria.

DEPLETABLE - Capable of being used up - often said of mineral resources, water, and mineral.

DEPOSITION - The accumulation of material dropped because of a slackening movement of the transporting material - water or wind.

DESERT - A dry region characterized by less than 25 cm (8 in.) of rain per year, where less than 20 percent of the ground is covered by permanent vegetation. Desert Grasslands and Desert Scrub in Arizona receive more annual precipitation (up to 12 inches), but are characterized by very arid conditions most of the year.

DIVERSITY - The differences between organisms; consisting of a good variety of species.

DOMESTICATE - Adapting to life in intimate association with man for the advantage of man; includes both plants and animals.

DORMANT - A period during which growth ceases.

ECOLOGY - The study of the interactions of plants and animals with their physical environment and with each other.

ECOSYSTEM - All organisms in a community plus the associated living and non-living factors and influences.

EFFLUENT - Solid, liquid, or gaseous wastes that enter the environment as a by-product of man-oriented processes.

ENDANGERED SPECIES - Species in peril of becoming extinct.

ENERGY CYCLE - (Food Cycle) - The series of events whereby energy is transmitted (in the form of food) from the sun to the soil to the plants, to animals, and returned again to the soil.

ENVIRONMENT - (Habitat) - The sum total of all biological, chemical, and physical factors that determine an organism's form and survival.

EROSION - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

EVAPOTRANSPIRATION - The loss of water from the soil by evaporation and transpiration from the plants in the soil.

EVERGREEN - Trees and shrubs characterized by small, compact leaves covered by a thick cuticle that holds in water and are not entirely shed at the same time (as deciduous trees).

FOOD CHAIN - (Energy cycle, food web) - A series of organisms that feed one on the other, usually starting with plants and ending with predators.

FOOD WEB - An interconnected series of food chains.

FORAGE - Grazed or browsed plants for animals.

FUNGUS (FUNGI) - A group of saprophytic and parasitic lower plants that lack chlorophyll, including molds, rusts, mildews, smuts, and mushrooms that live on other plants and animals.

GEOLOGIC HABITAT - A habitat is a "home" for something whether it be plant, animal, or mineral. Conditions control where things are and geologic habitat controls where useful geologic materials are.

GEOLOGY - The science that deals with the earth (or other planet) by studying its materials, their arrangement, and natural processes (events) both past and present.

GERMINATE - Development of a seed into a small plant.

GRASSLAND - (Desert Grassland, Plains Grassland, Forest Grassland) - An area characterized by sod forming or bunch grasses with periodic droughts, rolling terrain, and hot and cold seasons.

GROUNDWATER - Water held in the pores of soil or rock above an impervious layer and which can be removed through drainage or pumping

HABITAT - An area where a plant or animal lives which provides all of the essentials for life (i.e., food, water, shelter, etc.).

HERBICIDE - A chemical that is used to kill weeds; a "chemical hoe."

HORIZON - A layer of soil or soil material approximately parallel to the land surface and differing from adjacent, genetically related layers in physical, chemical, and biological properties or characteristics.

HYDROLOGIC CYCLE - (Water cycle) - The series of events whereby water is distributed and circulated in all of its various forms (snow, rain, vapor) throughout the earth and atmosphere.

HYDROSHPERE - The earth's water (oceans, lakes, moisture, groundwater, etc.).

IGNEOUS - Related to molten rock (magma). A group of rocks that has magma in its reason for being.

INFILTRATION - The downward entry of water into the soil.

INTEGRATED PEST MANAGEMENT - (IPM) - The method of controlling pests (mostly insects) utilizing various physical and chemical controls and habitat modification before resorting to poisonous chemicals.

INVADER PLANT - A plant that moves into an area and propagates; usually occurs during periods of stress, when native plants are decreasing.

INVERSIONS - Normally air is warmer closer to the earth's surface, however, during an inversion a layer of warm air traps a layer of cooler air next to the earth's surface.

IRRIGATION - The application of water to the land for the purpose of growing plants; the water may be applied by flooding, sprinkling or with a drip system

JOJOBA - A desert plant species with evergreen leaves and a bean which produces oil similar to the sperm whale.

LEACHING - The removal from the soil or from a higher horizon into a lower horizon in solution of the more soluble materials by percolating waters.

LICHEN - An organism composed of an alga and a fungus symbiotically associated, usually found on rocks where decomposition of the rock is taking place - an important life form of the Tundra.

LIFE CYCLE - (See Cycles) - The stages through which a plant or animal passes from fertilization of egg and maturity and fertilization of a new egg.

LITHOSPHERE - The outer part of the solid earth. What you live on and above.

MACRO - Large scale, such a macro-habitat or macro-environment involving entire moutain ranges or a continent.

MATURE SOIL - A soil which has had a long geologic time to develop and usually has distinct A, B, and C horizons.

METALLIC - Having the appearance of metal. Often said of minerals that have a metallic look.

METAMORPHIC - Changed form. Applied to a group of rocks that owe their characteristics to the changing of other rocks at depth by heat and/or pressure (short of actual melting). The type of metamorphic rock is controlled by specific environmental conditions that prevailed within the zone of metamorphism.

MICRO - (Habitat, environment) - Small scale, such as the mirco-habitat under a rock or the micro-environment in a small puddle.

MINERALS - What rocks are made of. Minerals are naturally occurring inorganic, crystalline solids with definite chemical and physical attributes (composition, hardness, etc.). As a kingdom, "mineral" refers to all substances that are not animal or vegetable. "Crystalline" (interior) is to be distringuished from "crystal" (exterior).

MOLD - A superficial wooly growth on a decaying or living organism (See saporphyte or parasite).

MESQUITE - (Mess-keet) - A desert species of tree or shrub commonly inhabiting draws or gullies which has invaded much of southern Arizona's grassland.

NATURAL CYCLE - (See Cycles) - Any one of a number of cycles which occur in the natural environment and involve plants or animals, or both.

NATURAL RESOURCES - Plants, animals and minerals which exist in the natural environment and are not man-made; includes air and water; usually divided into renewable and non-renewable.

NATURAL SELECTION - A natural process tending to cause the "survival of the fittest" individual or group of plants or animals to the environment in which they live; selecting for the most desirable genetic qualities for continued existence of the species.

NECTAR - A sweet liquid secreted by certain glands in a plant.

NICHE - The way in which the organism interacts with the biotic and abiotic communities; what it eats (consumes), and what eats it; the place in which a plant or animal "fits" into the habitat and the food web.

NITROGEN CYCLE - (See Cycles) - The natural process by which the gas, nitrogen, passes from air to soil and water, to plants and animals, through decay nitrogen fixation and back into plants again. (See diagram, figure ___)

NONMETALLIC - Not having a metallic appearance. Often said of rocks and minerals that are not metallic (limestone, clay, stone, gypsum, salt, etc.).

NONRENEWABILITY - A concept that recognizes that most earth processes occur so slowly that the quantities of most useful geologic substances cannot be significantly increased during the relatively short time frame of human existence. An attribute of most useful mineral, rock, and energy-materials deposits. There is only one crop of minerals. If you can't grow it you must mine it.

NONRENEWABLE - Natural resources that do not naturally replenish themselves within the limits of human time.

ORGANIC MATTER - The dead plant and animal matter in various stages of decomposition found on top of and in the soil profile.

ORGANISM - Any living thing.

PARASITE - A plant or animal that depends entirely upon another living plant or animal for its total survival (see saprophyte).

PERCOLATION - The downward movement of water through soil.

PERENNIAL - (See also Annual, Biennial) - A plant that persists in whole or part from year to year, such as trees, shrubs and perennial grasses.

PERMANENT WATER - A water source which is either not affected by climatic cycles or does not go dry during extended periods of drought.

PESTICIDES - Chemical compounds utilized to control pests (usually insects; also weeds and vertebrates).

PHEROMONE - An odorous chemical produced by animals and insects which influences (attracts or repels) other animals or insects of the same species; used artificially to trap or confuse insects from mating by "jamming" their sense of smell.

PHOTOSYNTHESIS - The process by which green plants use light energy in the presence of chlorophyll to convert water and carbon dioxide to carbohydrates and oxygen.

PHYTOPLANKTON - Aquatic, free-floating photosynthetic organisms (plants) as opposed to zooplankton which are aquatic animals: plankton float freely without control over direction, but simply drift with the currents.

PISTIL - The female part of the flower composed of the egg-bearing ovum, the style, and the stigma at the top which receives the pollen (male cells) which fertilize the eggs in the ovum.

PLANT COMMUNITIES - A group of plants inhabiting and interacting within the same environment.

PLANT LIFE - The term applied to all plants in general, including all of the green and non-green plants as distinquished from animals which move about from one place to another and derive their total subsistence on plants.

POLLEN - The small (microscopic) male cells that usually appear as fine yellow dust produced by the stamen (male organ) of the flower.

POLLINATE - The transfer of pollen from the male part of the flower (anther) to a receptive female part of the flower (pistil).

POROSITY - The degree to which the total volume of a soil, sediment, or rock is permeated with pores or cavities, generally expressed as a percentage of the whole volume unoccupied by solid particles.

PRECIPITATION - Hail, mist, snow, and rain: annual precipitation being the total amount of moisture falling on a given point.

PROTEIN - A combination of amino acids: the "building blocks" of plants and animals, essential for growth.

PROFILE - A vertical section of the soil from the surface through all its horizons, including the C horizon.

RANGE - (See Animal Life for another definition) - Synonymous with rangelands; an area or plant community consisting mostly of grasses where livestock graze.

RENEWABLE - (Natural resources) - Being able to perpetuate naturally and continuously, such as trees, grasses, wildlife, etc.

RECLAMATION PROJECT - A project, generally in the western United States, by which a water supply is developed, usually with dams on a river, to allow irrigation of nearby lands.

RECYCLING - The recovery of any material for reuse (aluminum cans etc.). Usually considered a form of conservation.

RESIDUAL - A soil formed in material weathered from bedrock without transportation from the original location.

RESPIRATION - The exchange of oxygen for carbon dioxide in the cells of animals which produces energy for life functions and heat as a by-product of metabolic chemical reaction; also the act of breathing in terrestrial animals.

RIPARIAN - (See Plant Communities) - Living on or adjacent to a water supply such as a riverbank, lake, or pond.

ROCK - A significant part of the solid earth that is made from minerals gathered together by crystallization and/or depositional processes. A specific result is the product of a specific set of environmental conditions (a "habitat") that prevailed in the past.

SAND - Particles of soil material that can be easily seen with a magnifying glass - it feels gritty.

SAPROPHYTE - A plant that lives on dead or decaying organic matter.

SAVANNA - A grassland plain with scattered trees where wet seasons and dry seasons may be extreme.

SEASONAL CYCLE - (See Life Cycle) - Sequence of periodic changes in plant life according to the time of year: spring, summer, fall and winter.

SEDIMENTARY - A group of rocks and materials collected by and/or deposited from water, wind, or ice. Type of sedimentary substance is controlled by a set of prevailing conditions at a given time and place, past or present.

SILT - Small particles of soil material that can be seen with a microscope - it feels smooth and velvety when wet.

SOIL HUSBANDRY - The business of caring for and managing the soil.

SOIL MATERIAL - Unconsolidated and more or less chemically weathered mineral matter from which soils are developed.

SOIL SERIES - A group of soils having horizons similar in differentiating characteristics and arrangement in the soil profile, except for texture of the surface portion.

SOIL STRUCTURE - The combination or arrangement of primary soil particles (sand, silt, and clay) into secondary particles.

SOIL TEXTURE - The relative proportions of the various soil separates (sand, silt, and clay) in a soil.

STAMEN - The male organ of a flower, consisting of a filament and an anther.

STOMATA - A minute opening in the leaf through which the gases exchange.

SUBSOIL - The B horizons of soils with distinct profiles or the soil below the plowed soil layer, in which roots normally grow.

SUBSURFACE WATER - Referring to water contained in the soil or rocks below the earth's surface

SUCCESSION - (Geologic, ecologic, plant, animal) - The orderly progression of biotic changes in a community; especially in plant succession, the sequence of changes from bare ground to weeds, grasses, shrubs, and trees depending upon the ecological conditions (see climax).

SUCCULENT - A plant with fleshy tissue to absorb moisture.

SYMBIOSIS - When two organisms (plants or animals) live together to the mutual benefit of each other.

TERRESTRIAL - Soil bound; as a terrestrial plant or animal which inhabits a terrestrial habitat primarily on land as opposed to an aquatic (water) habitat.

TILLABLE - The ability to operate implements through the soil to prepare seedbeds and rootbeds, control weeds and brush, aerate the soil, and cause faster breakdown of organic matter and minerals to release plant foods.

TOPOGRAPHY - The configurations of the surface of land which include mountains, valleys, cliffs, canyons, hills, etc.; topographic and relief maps are designed to show these features as well as man-made changes in the contours and drainage.

TOPSOIL - The surface plow layer of a soil; sometimes called surface soil and often relating to the A horizon.

TRANSPIRATION - The loss of water vapor through the stoma in plants; corresponds to perspiration in animals.

TRANSPORTED - Soil which has been moved by wind, water or gravity to a new location.

TYPE - See soil series.

VIGOR - Active growth of a plant indicated by the height and amount of foliage.

WATER CYCLE - (See Hydrologic Cycle)

WATER TABLE - The upper surface of the groundwater or that level below which the soil is saturated with water.

WATERSHED - An area where water falls and drains through; for example, the slopes and the valleys in a mountain range.

WEATHERING - The disintegration and decomposition of rocks and other earth materials through exposure to the atmosphere.

YOUNG SOIL - A soil which has been forming for a relatively short geologic time and usually has only an A and C horizon or, if present, only a poorly developed B horizon.

REFERENCES

Benson, Delwin E., 1977. "Helping Wildlife: Working With Nature". Wildlife Management Institute, Washington, D.C.

"The Beaver Creek Program, Advancing Forest and Range Resource Management", August 1977. Rocky Mountain Forest and Range Experiment Station, Forestry Science Laboratory, Northern Arizona University, Flagstaff, Arizona.

Brown, David E., and Charles Lowe. "Biotic Communities of the Southwest". General Technical Report RM-78, Rocky Mountain Forest and Range Experiment Station. USDA Forest Service, Tempe, Arizona.

Brown, David E., Editor. "Desert Plants - Biotic Communities of the American Southwest - United States and Mexico", 1982. University of Arizona, Boyce Thompson Arboretum, Superior, Arizona.

Curtis, Helena, 1979. "Biology", Third Edition, Worth Publishers, Inc., New York, New York (1043 pp.).

"Gardening With Wildlife". National Wildlife Federation, Washington, D.C. (190 pp.).

Lowe, Charles, 1980. "Arizona's Natural Environment". University of Arizona Press, Tucson, Arizona (136 pp.).

Martin, Alexander D., Herbert S. Zim and Arnold L. Nelson. "American Wildlife and Plants, A Guide to Wildlife Food Habits", 1951. Dover, New York (softbound, 500 pp.).

Odum, Eugene P., 1963. "Ecology". Holt, Rhinehart and Winston, New York, New York (softbound, 152 pp.).

Owen, Oliver S., 1975. "Natural Resource Conservation, An Ecological Approach", Second Edition, MacMillan Publishing Company (700 pp.).

Project Learning Tree, Western Regional Environmental Education Council, American Forest Institution, Washington, D.C.

Smith, Robert L., 1966. "Ecology and Field Biology". Harper and Rowe, New York, New York (68 pp.).

Water, 1955. Yearbook of Agriculture, U.S. Department of Agriculture. U.S. Government Printing Office, Washington, D.C.

"Landscaping with Native Arizona Plants", Natural Vegetation Committee, Arizona Chapter, Soil Conservation Society of America. University of Arizona Press, Tucson, Arizona (194 pp.).

Schery, Robert W., 1972. "Plants for Man", Second Edition, Prentice-Hall, Inc., Englewood Cliffs, New Jersey (657 pp.).

Sellers, William D., and Richard H. Hill, 1974. "Arizona Climate 1931-1972". The University of Arizona Press, Tucson, Arizona.

Muller, Robert A., and Theodore H. Oberlander, 1978. "Physical Geography Today: A Portrait of A Planet", Second Edition, Random House, New York.

Rumney, George R., 1968. "Climatology and the World's Climates". McMillan Co., New York.

Miller, Albert, and Jack C. Thompson, 1970. "Elements of Meteorology". Chas. E. Merrill Publishing Co., Columbus, Ohio.

Flohn, Hermann, 1969. "Climate and Weather". McGraw-Hill Book Co., New York.

Sellers, William D., 1965. "Physical Climatology". University of Chicago Press, Chicago.

Bulk, Harold C., 1985. "Useful Climate Data for 38 Arizona Locations". Laboratory of Climatology, Arizona State University, Tempe, Arizona.

USDC, "Climatological Data for Arizona". National Climatic Data Center, NOAA, Asheville, North Carolina.